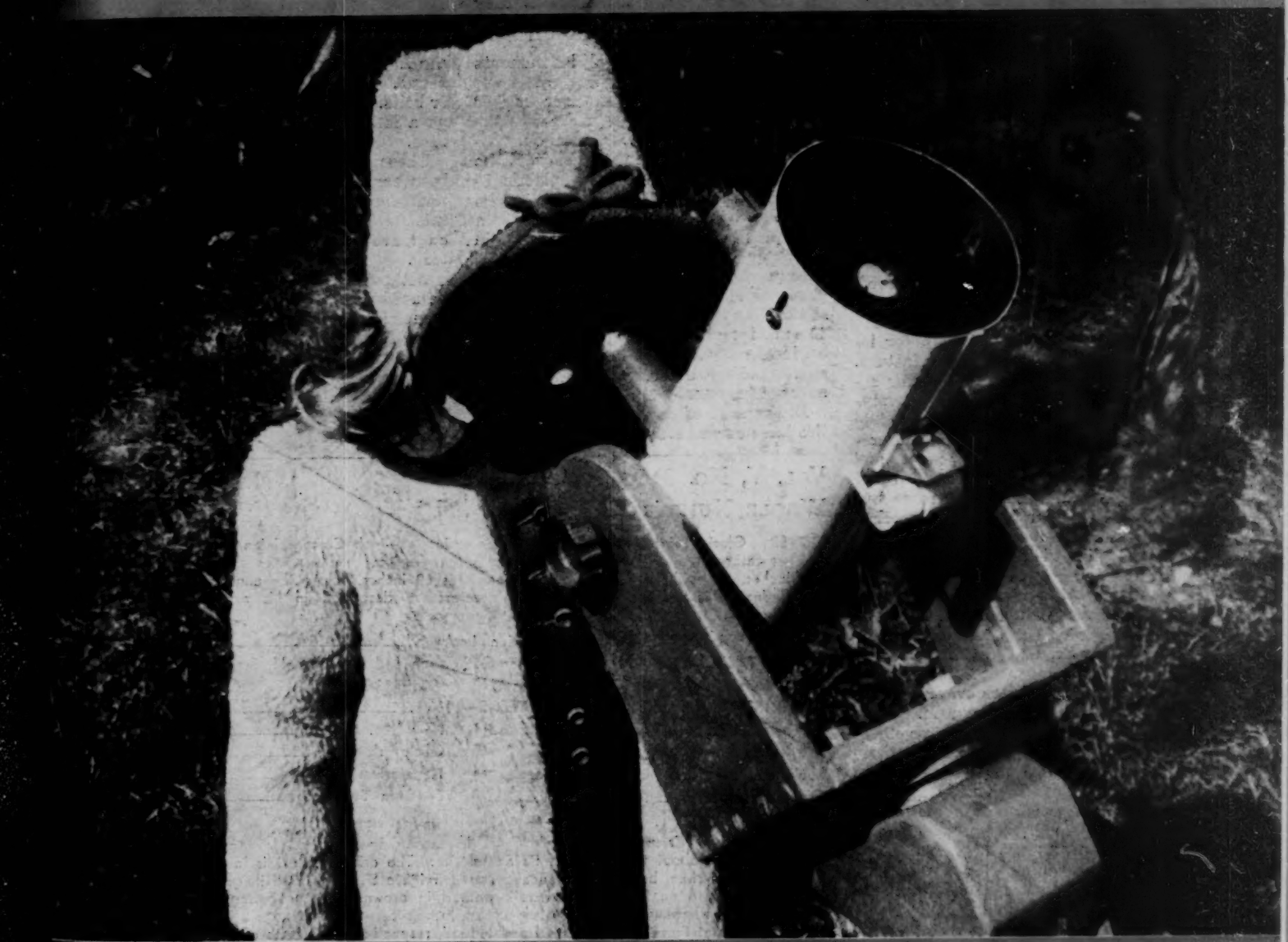
JAN 3 1946

Sky and TELESCOPE



A 2-year-old observer and a 4-inch Cass

Vol. V, No. 3
JANUARY, 1946
Whole Number 51
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In This Issue:

Stars of a Winter's Night

Loran Tables and Charts

Cosmogonical Implications of the Atomic Bomb—III

Graphic Time Table of the Heavens—1946

Northern and Southern Star Charts

The Editors Note . . .

OPTICAL PLASTICS have been developed almost entirely under the impetus of wartime necessity; the story of the research in this interesting field has now been released, and we find the results hold some promise for the future development of astronomical instruments made in part or wholly of plastic.

It was to provide a method for the mass production of lenses and prisms needed by hundreds of thousands in artillery sights, range finders, binoculars, and other optical instruments used in combat, that even before the war began the National Defense Research Committee began to study methods of molding optical elements from plastic. At that time, the best-known plastic for such purposes was methyl methacrylate—Lucite—but it had poor optical qualities as well as other faults. Therefore, the Polaroid Corporation, of Cambridge, Mass., which had the NDRC contract for this research, investigated the potentialities of some 113 different plastics, but found only two that gave satisfactory results when all factors were considered.

These two plastics are polycyclohexyl methacrylate (CHM) and polystyrene (styrene), the latter well known for its part in synthetic rubber manufacture. CHM has an index of refraction for sodium light of 1.50645; the index for styrene is 1.59165, so they may be used to make achromatic lenses, CHM corresponding to the crown component, and styrene replacing the flint element. CHM has a low softening temperature (about 70 degrees C.), and is easily scratched and abraded. Styrene has 16 per cent shrinkage while it is polymerizing (liquid molecules joining to form chains) in the mold, and its surface accuracy limits its use to low-power instruments. Styrene is also easily scratched, and has a relatively high coefficient of expansion.

Most disadvantages of plastics in manufacture and use were overcome during the NDRC research program. Cover glass was used to protect telescope objectives and eyepieces; completely athermalized systems with plastics cases were produced; one glass element in a plastic system could be made to provide all the "power," and temperature changes in the plastic elements had no effect. Means for surface hardening of plastics were found, both at Polaroid and at the California Institute of Technology.

The manufacturing technique lends itself readily to mass production by unskilled and semiskilled workers. CHM is synthesized chemically from raw materials; styrene is purified from the commercial grade. Both monomers are partially polymerized, becoming very viscous, before being poured into pyrex molds shaped like the prisms, lenses, and mirrors which are to be cast. These molds, prepared by the usual optical methods, may be used hundreds of times, thereby reducing production costs considerably. The finished plastic elements are freed from the molds in warm water and then baked to relieve strains. There is no grinding or polishing of their surfaces; in fact, from the moment they leave the mold these finished surfaces must be protected against abrasion.

Nearest to astronomical instruments are low-power telescopes and binoculars made of optical plastics. For higher powers, improved surface accuracy, better internal homogeneity, and elimination of haze and color in styrene would be required. For the Army, a plastic 3-power anti-tank telescope with a 6-inch eye relief and 1-inch exit pupil proved a boon possible of immediate production in large quantity. A satisfactory aerial camera, f/2.8, comprising four plastic elements and one of glass, has been designed and constructed. A 6-power, 40 mm. inverting telescope would suit a beginning student of the moon and the sun. Galilean binoculars would interest nature students.

In the field of aspherical optics, plastics have earned a secure place. Twenty thousand completely plastic Schmidt systems were produced for one wartime need. Probably the entire Schmidt system in your future television receiver—correcting plate, mirror, and housing—will be of optical plastic. Associated with this aspherical development is that of elements for peculiar systems where the mirror is off axis, or must have holes bored in it, or must be tapped for screws or bolts. Plastic elements may be turned on a lathe, sawed, drilled, and cut with ease.

These optical plastics researches have been carried out under Section 16.1, Optical Instruments, of NDRC. Chief of this section is Dr. Theodore Dunham, Jr., on leave from Mount Wilson Observatory.

Although elements of plastic cannot be used for the precision required in astronomical instruments, the future may bring further improvements, but perhaps without the emergency of war there will be little incentive to overcome the physical and chemical difficulties still in the way of making a perfect optical element of plastic.

Sky and TELESCOPE

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VOL. V, NO. 3 JANUARY, 1946
WHOLE NUMBER 51

CONTENTS

COVER: Gloria Leight, at the age of three, using a 4-inch Cassegrainian reflector made by her father, Walter Leight, of North Hills, Pa. The overall length of the telescope is 12 inches, although the effective focal length is 60 inches. Note the unusual design of the finder. This and Mr. Leight's other reflectors are described in his article beginning on page 18.

STARS OF A WINTER'S NIGHT—Marian Lockwood 3
LORAN TABLES AND CHARTS—Fletcher G. Watson and Henrietta H. Swope 5
COSMOGONICAL IMPLICATIONS OF THE ATOMIC BOMB—III—Felix Cernuschi 8
GRAPHIC TIME TABLE OF THE HEAVENS—1946 12

Amateur Astronomers 11
Astronomical Anecdotes 15
Books and the Sky 18
Gleanings for A.T.M.s 14
News Notes 7
Observer's Page 16
Planetarium Notes 20
Southern Star Chart 23
Stars for January 22

BACK COVER: This portion of an official Loran Pacific Airways plotting chart has been reduced to about two thirds of its actual size. The original chart is in black and colors, the Q-G system, based on Nihau and French Frigate Shoal, printed in green, and the Q-J system, based on Nihau and Hawaii, printed in brown. All numbering and wording referring to a system is in the same color. In this case, Nihau is the master station, with the slaves at French Frigate Shoal and Hawaii, respectively. The lines of position are mostly 100 microseconds apart, but where these lines become well separated, additional 50-microsecond lines are inserted. (See page 5.)

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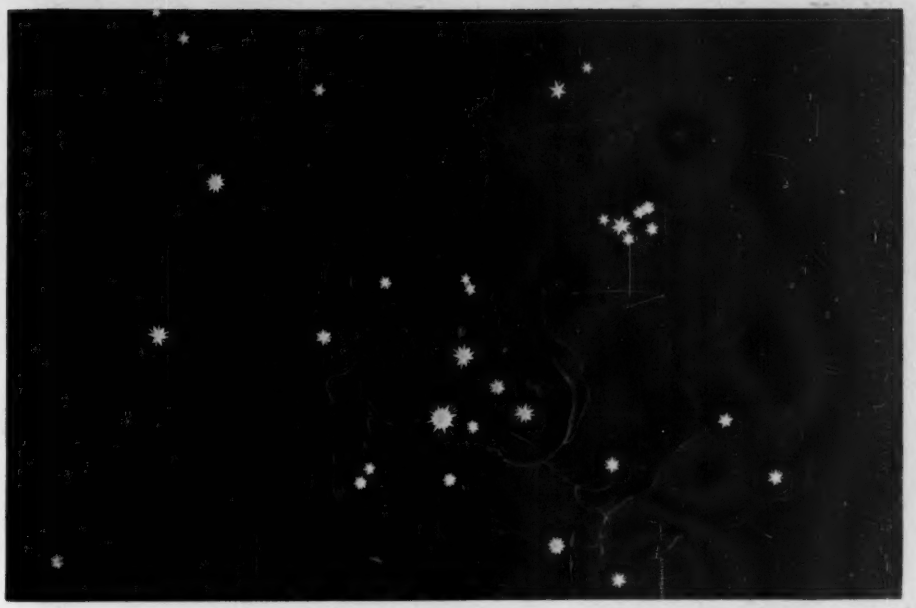


Taurus, the Bull, has bright red Aldebaran for his eye, the V-shaped Hyades for his face, and the Pleiades in his shoulder. Beta and Zeta Tauri mark the tips of his horns.

Stars of a Winter's Night

By MARIAN LOCKWOOD

Associate Curator, Hayden Planetarium

At no time does the celestial panorama appear more beautiful than in the crisp air of a winter's night. In the Hayden Planetarium this month, guide lines for the more prominent constellations are projected on the planetarium sky.

THE constellations are usually divided into four groups, those of spring, summer, autumn, and winter. But these groupings are purely arbitrary since on any one clear night an observer can see, if he watches from dark to dawn, much more than half the number of stars ever visible from his latitude; this is, of course, especially true in the winter when nights are long. The arbitrary choice usually centers on the constellations which are visible only during the greater part of the night, leaving out those which are in the western part of the sky at sunset and in the eastern sky at dawn. These other constellations which are visible for a shorter period of the night do, however, make up an important part of any night sky and should not be left out of consideration.

In the winter sky, the constellations Orion, Canis Major, and Taurus are often listed as the most important groups of the season. This is obviously a good choice, for the three constellations fill one solid block of the sky which is visible most of the night, moving slowly across the heavens from the east in the early evening to the western horizon by dawn. However, in the early-evening sky of early January, stars which are usually listed as those of autumn can be seen in the *western* sky—such constellations as Cygnus, Pegasus, Pisces, and Andromeda. In the early-morning sky of early January, Bootes and Virgo add their beauty to the silver panoply of the *eastern* heavens.

One of the first and most important considerations for the amateur star-gazer is to be sure that he knows the directions of the four points of the compass. The observer who does not know his directions is in the same difficulty as the man who asked for planetarium help in the identification of a particularly bright star he had seen a few nights before. When asked in what direction he had seen the star, he replied hopefully, "Why, it was right over my garage."

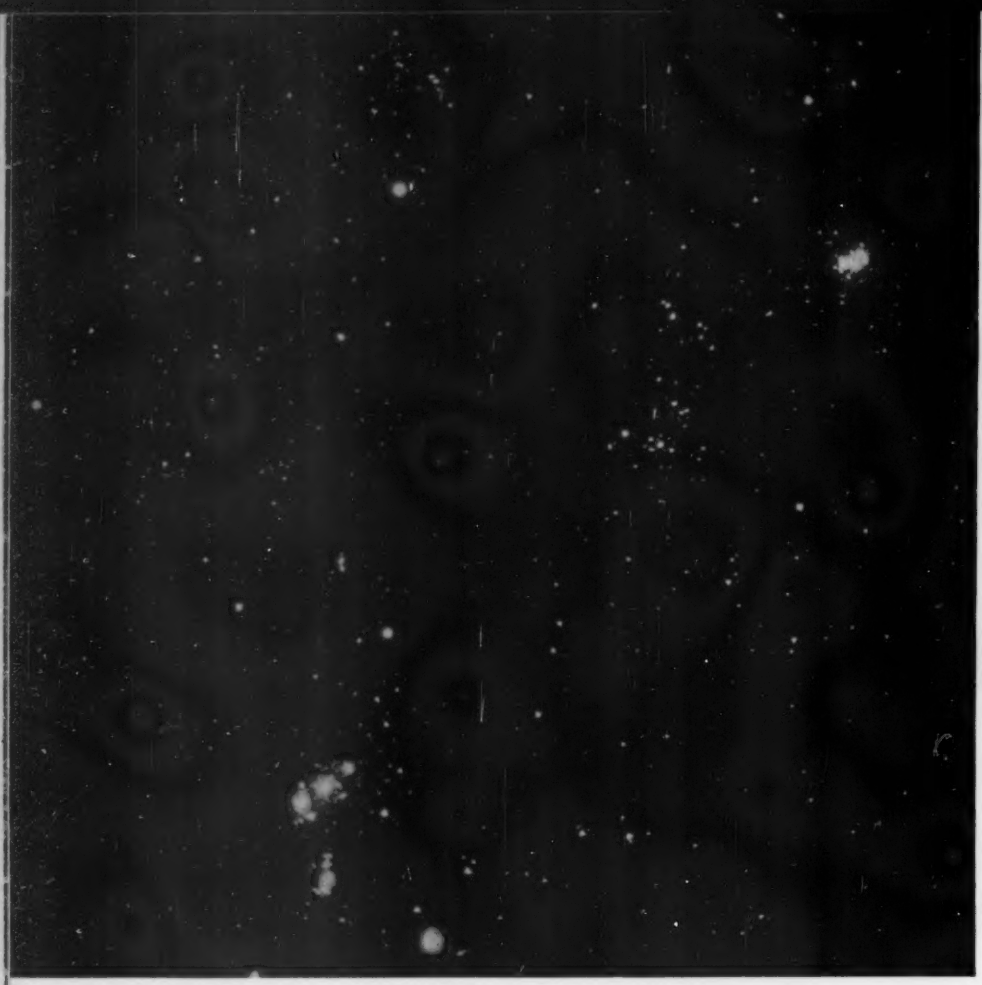
A chart of the sky from Taurus to Canis Minor and Canis Major. Part of this region appears in the photograph on the next page.

To most amateur astronomers the three outstanding constellations of the winter sky are more or less an old story, but a story which stands frequent repetition because it treats of stars of great beauty and scientific interest.

Orion, generally conceded to be the loveliest and most striking of all constellations, stands midway in the sky, his feet in the southern hemisphere and his head raised loftily north of the equator. The top star of his belt, Mintaka, is almost exactly on the celestial equator. This strategic position makes Orion a familiar figure in all parts of the world, although to an observer at the north pole of the earth only the upper half of his body would be visible, and at the south pole only the lower half. Orion straddles the meridian, that is, it is due south, at approximately 11 p.m. on the first of the month, and about 9 p.m. on the last night of January. The two-hour difference in time is related to the fact that any given star rises about four minutes earlier on succeeding nights, a difference of two hours in one month's time.

Orion is easily recognized by its enormous oblong of four bright stars, diagonally crossed by a line of three 2nd-magnitude stars evenly spaced and three degrees in length. The brilliant star in the northeastern corner of the oblong figure is Betelgeuse, which shines with a definitely orange-red light, marking the Hunter's right shoulder. Betelgeuse is one of the largest stars known, a real giant whose size, as well as its brightness, varies. The star ranges from 260 to 360 million miles in diameter. If it were possible to transfer both the earth and the sun to the interior of Betelgeuse, the earth could go on moving around the sun and at all places in its orbit it would be beneath the surface of Betelgeuse.

Diagonally across the oblong figure from Betelgeuse is Rigel, a stunning blue-white star which marks the left foot of the figure. Rigel's distance is not very definitely known, but is probably about 540 light-years, in which case it is about 21,000 times as bright



Taurus and Orion, winter constellations. As the photograph was taken on a blue-sensitive plate, red stars such as Aldebaran and Betelgeuse are inconspicuous, while very blue stars, for instance Nath (Beta Tauri), the Belt stars, and Rigel, are overexposed.

as the sun, which makes it one of the intrinsically brightest stars known.

In addition to the enchanting beauty of the constellation figure, Orion has still another claim to fame. Hanging from the three-starred belt is a line of fainter stars which, according to tradition, marks the great hunter's sword. Along the line of the sword lies a jewel of bewitching grace—unique even among the countless splendid gems of the sky—the Great Nebula, an object which can be just glimpsed by the naked eye.

By following the line of Orion's belt to the east, the observer discovers the star Sirius, otherwise known as the Dog Star, the most brilliant stellar object in the heavens. Sirius shines with a piercing blue-white light, magnitude —1.6. Its great brightness is due partially to the fact that it is one of the nearer neighbors of the sun, at a distance of less than nine light-years or about 50 trillion miles. Its intrinsic brightness is about 30 times that of the sun. The white dwarf star which is the companion of Sirius is only about 1/10,000 as bright as Sirius itself. It is known to be an extremely dense object, of which one pint at the surface of the earth would weigh about 25 tons.

The line of Orion's belt, if used as a guide line in a general westerly direction, leads to Taurus, the Bull, one of the most ancient of the constellation figures. Some 4,000 years ago, the vernal equinox was located in this group of stars, but because of its constant motion toward the west, due to precession, the vernal equinox is now to be found in the constellation Pisces, south of the Great Square of Pegasus.

Taurus is rich country for the amateur to explore. Very conspicuous is the V-shaped group of stars which forms the face of the Bull, with the brightest star in the constellation, Aldebaran, at the eastern point of the V. With the exception of Aldebaran, the stars in the V belong to a group known as the Hyades, an open or galactic star cluster. Aldebaran itself is about 53 light-years distant, while the stars in the Hyades are about 125 light-years away.

Taurus boasts another superb galactic cluster, the Pleiades, better known than the Hyades and even more conspicuous as a cluster. The Pleiades are to the west of the Hyades. The average person can with his unaided eyes see six stars in this group, although those with exceptional eyesight may see as many as eight or nine. Through a telescope, the Pleiades are seen to comprise hundreds of stars. This type of cluster is called "galactic" because most of the 400 such clusters so far observed occur within about 15 degrees of the galactic equator.

West of Canis Major and south of Orion the observer will discover a neat and attractive group of stars, the constellation Lepus, the Hare. An irregular quadrilateral of 3rd- and 4th-magnitude stars is the most conspicuous formation here, with a curved line of three faint stars forming the Hare's back. Four faint stars south of Rigel mark the ears. Gamma Leporis (which can be found on the star map for this month) is an easy double for good binoculars. Lepus is famous for the beautiful blood-red star known as Hind's crimson star, which is the long-period variable, R Leporis, ranging from 6th to 8th magnitude.

For those who want new lands to conquer, the constellation of Monoceros, the Unicorn, offers some possibilities. It is an extremely faint group of stars, hard to pick out and define. Its position is to the east of Orion, and, roughly speaking, between Canis Major and Canis Minor. No one of its stars is brighter than 4th magnitude. Although because of its faintness this constellation is not generally well known, it is a field rich in star groups and clusters.

Eridanus, the River, is another less conspicuous constellation, but one rich and fascinating in the wealth of mythological lore associated with it. Known to Virgil, it was named by him "the King of Rivers." Many early observers believed it to be the heavenly counterpart of the River Nile. Eridanus begins its wanderings close to Rigel. Follow its course on the map (page 22); then, turning to the real sky, identify there its interesting curves and backturns. The lucida of this group, Achernar, is too far south of the celestial equator to be seen in most of the United States, but is a circumpolar star for observers living 33 degrees south of the equator.

In the sky of January, 1946, the stars play their usual part in the perfection of the winter scene. But their beauty is greatly augmented this year by the conspicuous presence of three planets. Mars and Saturn rise very soon after darkness falls; Jupiter rises about midnight. On January 14th, Mars will be in opposition to the sun, when it rises about at sunset and is visible all night long. Saturn will be in opposition to the sun on January 12th. On January 10th Mars comes closest to the earth. On January 22nd there will be a conjunction of Mars and Saturn with Mars north nearly 4½ degrees.

LORAN TABLES AND CHARTS

By FLETCHER G. WATSON, Lt. Comdr. USNR, and HENRIETTA H. SWOPE
of the *U. S. Naval Hydrographic Office*

THE ARTICLE last month gave a general description of loran and suggested the magnitude of the establishment necessary to maintain the far-flung stations. The transmitting stations and the receiving equipment, developed through the application of novel conceptions of electronics, are the basis of the system and make loran possible. However, without tables and charts all the equipment and its careful operation are without meaning; the tables and charts permit the translation of time differences into navigational information.

The value of loran and the use of loran charts is well illustrated by a report from the Aleutians: "A Ventura bomber, while on a mission over the Kuriles, was hit by a burst of antiaircraft fire which threw the plane over on its back and destroyed the radar, compass, and other instruments. The LORAN gear was still in operating condition, however, and by homing on a line of position from rate zero the plane was able to reach its home base."

The Hydrographic Office became responsible for the production of loran interpretative material when the Navy took over operations on January 1, 1943. Loran was just emerging from its experimental stage; three pairs of stations were operating along the Atlantic coast of the United States and Canada, while two more pairs in Newfoundland and Greenland were under construction. When the first chart was printed in April, 1943, 500 copies seemed overly optimistic. Within two years chart requirements had jumped to tens of thousands per month.

Inasmuch as loran involves a new technique in position finding, a discussion of the problems encountered in the preparation of the tables and charts may be of interest. There are four distinct stages of work: (1) obtaining accurate co-ordinates for the transmitting stations, (2) computing the basic tables, (3) drafting and printing the charts, and (4) distributing them rapidly to navigators. The urgency of military necessity has often prevented as elaborate or careful investigations of methods as might be desired. But the Hydrographic Office was expected to produce satisfactory material and to have it in the hands of navigators by the time new stations went on the air.

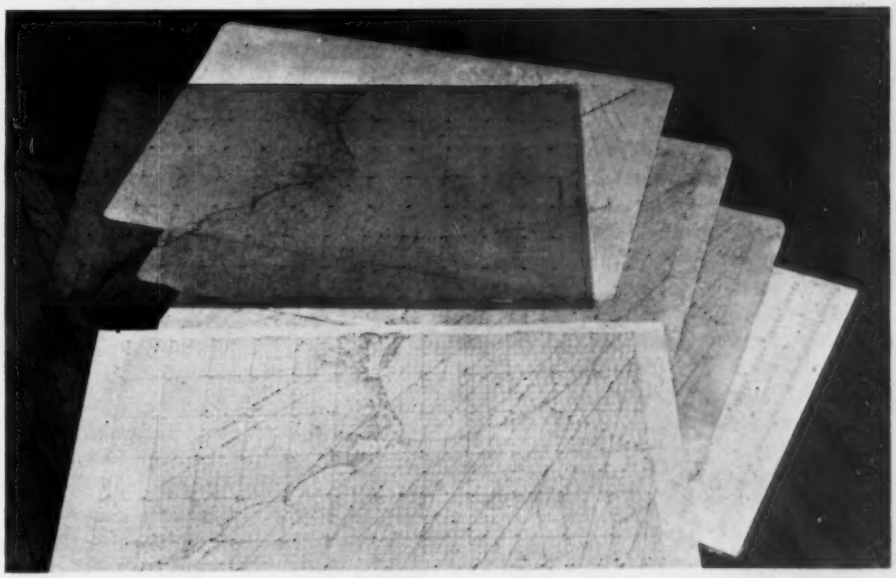
Accurate co-ordinates for the stations can be obtained easily where a triangulation grid exists, as along the shores of the United States. But in many of the places where stations were constructed, on isolated islands and atolls throughout the Pacific Ocean, no triangulation existed or could be made. Therefore, the Hydrographic Office sent observers and astronomical equipment with the siting parties that selected the positions of the transmitting stations. As expected, it was soon obvious that many of the unfrequented islands were several miles from their previous charted positions; for example, Makin Island was six miles north and St. Matthews Island in the Bering Sea was eight miles east of the respective charted locations.

Use of astronomical co-ordinates for the stations introduced a vexing problem: gravitational deflection of the vertical.[1] The islands of the Pacific rise steeply from deep water, so there is an abrupt change in density from water to rock. This discontinuity produces local bulges in the gravitational field of the earth with the result that the gravitational zenith is deflected away from the denser island. But any astronomical observation is dependent on the gravitational vertical and, therefore, is subject to this type of systematic error. Because a pair of stations usually "face" each other and are deflected toward each other, a baseline calculated from the astronomical co-ordinates will generally be too short.

The maximum reading produced by a loran pair is twice the distance between the transmitters plus a constant; thus the distance between the stations is an important quantity, and a change of 500 feet in the separation of the stations appears as an error of one microsecond on the master baseline extension. As 500 feet is equivalent to five seconds of arc, displacements of the stations by more than this amount can be and are detected. The magnitude of the potential trouble is evident when it is noted that the largest deflection known, on Hawaii Island with its two great volcanoes, is 64 seconds of arc!

Since there was insufficient knowledge to permit reasonable estimates of the gravitational deflections on atolls, the six stations installed in the Phoenix and Marshall Islands were treated as an experiment. The systematic errors of the patterns, which in one case ran up to eight microseconds, were investigated in detail and estimates made of the gravitational deflections causing them. Thereafter

[1] See "Eclipses and Earth Surveys," by Walter D. Lambert, *Sky and Telescope*, IV, 9, July, 1945.



Five separate drawings are required to produce this one loran chart. Official U. S. Navy photograph. A loran chart appears on this month's back cover.

it was possible to correct the astronomical co-ordinates for most of the deflection and to obtain patterns with little or no error. The Hydrographic Office has prepared correction diagrams that can be used with the tables and charts to eliminate residual systematic errors.

If the earth were flat, or even spherical, the computation of points on loran lines would be relatively simple, but the spheroidal shape must be taken into account in loran calculations. At any point, the ground-wave reading equals the sum of the baseline distance and the slave station delay, plus the difference in distance to the slave and to the master stations. All distances are computed directly in microseconds; the conversion factor used is 3.33676 microseconds per kilometer, equivalent to a velocity of propagation of 299,692 kilometers per second, or 983.2 feet per microsecond.

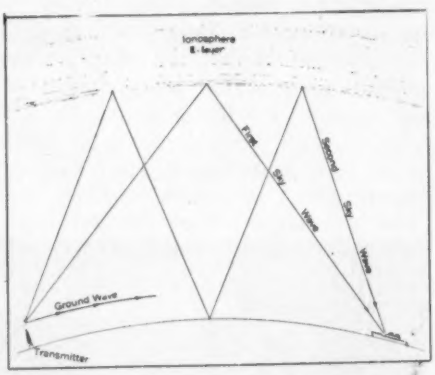
At the Radiation Laboratory, where the computational work was begun, a simple formula developed by Doolittle and used by the Coast and Geodetic Survey for arcs of moderate length was adopted.[2] When in March, 1943, the Hydrographic Office set up a computing office in New York City with a staff of about 40 persons, it was possible to take a more precise formula developed by W. D. Lambert[3], rearrange the terms for mass computation, and prepare the necessary auxiliary tables. With this formula, arcs of several thousand miles can be computed to an accuracy of about 20 feet, or 0.02 microseconds. For loran computations, the Clarke spheroid of 1866 has been adopted, since all the triangulation in North America has been referred to that spheroid.

The geometry of a hyperbolic line is relatively simple: it is the locus of points having a constant difference in distance from two fixed points. It would seem that if the co-ordinates of the stations were known, a specific difference in distance (loran reading) chosen, and one co-ordinate of a point on a line of position (say, the longitude) assumed, then the other co-ordinate (the corresponding latitude) could be calculated directly with some ease. Actually this is not so, for to date no tractable formula has been found. Thus, the direct solution for points on loran lines could not be made and an indirect approach had to be adopted.

When the co-ordinates of the transmitting stations are known, the time values of the distances to the slave and master stations are computed for a grid of points at whole degrees of latitude and longitude within 1,400 nautical miles. The ground-wave readings at these points are then found from the previously mentioned relationship. The navigator is not interested in these readings at grid points, but requires the co-ordinates of points having certain readings. These are found, generally at intervals of 20 microseconds, by inverse interpolation between the grid points.

Original estimates of the computation time per station pair ran around 10,000 man-hours; but improvements in computing techniques have reduced the effort to around 3,500 man-hours. Six volumes of tables, giving lines of position for 35 pairs of stations, are currently available, while a seventh volume with five more sections is in preparation. In addition, tables for a number of special or temporary installations were computed and issued in limited quantities or used in the preparation of charts.

Loran charts require skill in drafting and printing, for often as many as eight separate drawings must be accurately superposed. The basic material of a chart—grid, topography, land tint, and aviation data—is required. Over this are added the various loran patterns, each in its distinctive color. Any small distortion or error in registering a plate during the printing will produce a systematic error in the corresponding loran pattern. Careful attention is required during the press runs, which often totaled 50,000 copies of a single chart.



A diagram showing the direct ground-wave loran signal, and the signals bounced back to the earth from the ionosphere.

The distribution of loran charts has grown from a few hundred per month to a maximum of 354,000 in May, 1945. Even now, several months after the end of hostilities, over 100,000 charts are requested per month. The total wartime production, made mostly during 1944 and 1945, exceeded 2,250,000 copies.

As early as 1942, the possible use of mobile or temporary transmitting stations during certain military operations was foreseen. Considerable effort was given to devising and evaluating various methods by which approximate loran charts could be prepared rapidly in the field. The method adopted consisted of plotting plane hyperbolas on a Lambert conformal projection. Observable errors from distortion in the projection did not appear at ranges of several hundred miles, but beyond that distance they increased rapidly. A small number of readings were computed for grid points at long ranges and the plane hyperbolas displaced until they agreed with these computed values. When the first Coast Guard mobile unit began transmitting near New Guinea late in 1944, its field party on Morotai produced a goodly supply of charts which were accurate within a mile or two even at the maximum range of 1,400 nautical miles. By early 1945, transmitting stations were being installed in the western Pacific area very shortly after new territory became available. The interval required to prepare charts in Washington and to get them to users halfway around the world was too great, and an office for the preparation of temporary charts was established at Guam by the Hydrographic Office and the Coast Guard. Many thousands of these charts were produced; often less than a day after coming off the press they were being used by B-29 navigators.

All loran tables and charts are prepared on the assumption that ground waves should be used. However, sky waves must often be matched at ranges exceeding 500 miles. In that case, the additional delays in reception of the two signals must be considered and the sky-wave reading corrected for the difference of these delays. As a result of thousands of observations obtained for this purpose, the change of delay with distance from the station is rather well known. Thus, the sky-wave corrections can be listed in the tables and shown directly on the charts. Incidentally, these observations have revealed the potentialities of loran as a tool for ionospheric research. A continuous picture of the signal is presented and the "virtual height of reflection" constantly determined within a few hundred feet. A compari-

(*Continued on page* 17)

[2] For its derivation, see Hayford, "Figure of the Earth and Isostasy from Measurements in the United States," 1909, p. 88.

[3] W. D. Lambert, "The Distance Between Two Widely Separated Points on the Surface of the Earth," *Jour.* Wash. Acad. Sci., *32*, 125, 1942.

NEWS NOTES

By Dorrit Hoffleit

THE ARTIST OF PLANETARY PORTRAITS

"Eugene Antoniadi was an amateur in the best sense of the word." So eulogizes the British Astronomical Association, writing of the man who directed its Mars Section from 1896 to 1916. Antoniadi was born of Greek parents in Constantinople in 1870. Observations of the planets that he made as a youth of 18, with a 3-inch and later a 4½-inch telescope, attracted attention even in far-away France.

Some time thereafter, Antoniadi went to Paris where he worked with Flammarion. In 1909, Director Deslandres put at his disposal the giant 33-inch refractor there. A keen and industrious observer and an exceptionally talented draftsman, Antoniadi produced maps and drawings that have done much to further knowledge of the surface features of the planets.

His death at his home in Paris on February 10, 1944, has only now been confirmed.

AMERICAN ASTRONOMICAL SOCIETY TO MEET

On Friday and Saturday, February 1st and 2nd, the American Astronomical Society will hold its 74th meeting at Columbia University, New York City, on invitation of Professor Jan Schilt, director of the Rutherfurd Observatory there. The sessions will be held in the Pupin laboratory of physics.

The tentative program calls for four sessions for papers, one or more of which will be devoted to a symposium on double stars. A meeting of the Teachers' Conference will also be held.

The meeting of the society scheduled for late February, 1945, was cancelled because of wartime restrictions on travel and meetings.

HAPPY BIRTHDAY

The April-July, 1945, number of the *Reviews of Modern Physics* is dedicated to Niels Bohr in commemoration of his 60th birthday. After working for two years in Rutherford's laboratory in Manchester, Bohr returned in 1916 to his native Copenhagen, and there in 1920 helped found the institute for theoretical physics which, under his directorship, became recognized as the "capital of atomic physics."

No less than 35 illustrious names are found among the authors of the 26 contributions to the commemorative volume, each of whom "would like to express his individual debt of gratitude to Professor Bohr," whose illucidation of the structure of the atom is one of the most indispensable foundations of modern physics. Many of the authors have recently been cited for investigations of importance in the atomic bomb problem.

Papers of especial interest to astronomers include "Influence of the Expansion of Space on Gravitation Fields Surrounding the Individual Stars," by Albert Einstein and Ernst G. Straus; "Shell Source Model for Red Giant Stars," by G. Gamow and G. Keller; and "Formation of Absorption Lines in a Moving Atmosphere," by S. Chandrasekhar.

NOTED INSTRUMENT MAKER DIES

On November 11th, James Walter Fecker, optical instrument maker, died in Pittsburgh, where he had conducted an optical shop which produced astronomical instruments of all types. Mr. Fecker was well known to astronomers for his fine astronomical objectives, mountings, and his Schmidt-type telescopes. He designed and built the Copernican planetarium in the Hayden Planetarium in New York City.

HUBBLE RETURNS TO MOUNT WILSON

The radio talk Dr. Edwin P. Hubble gave over CBS during the Philharmonic Symphony hour on November 18th, "The Exploration of Space," symbolized one phase of the transition from war to peace. During the war years, Dr. Hubble worked at the Aberdeen Proving Ground, where he was head of the Exterior Ballistics Branch at the Ballistics Research Laboratory and in charge of the new supersonic wind tunnel. He had little time for extragalactic research and public astronomical lectures.

Early in December, Dr. Hubble returned to Mount Wilson Observatory, where he is to be head of the research committee and will resume his own studies of exterior systems. As he aptly remarked at the close of his broadcast, "The explorations will continue. Still greater telescopes will be put into operation. And slowly, as the darkness recedes, the universe will loom forth."

WEATHER AND THE E LAYER

For many years Dr. Charles G. Abbot, of the Smithsonian Institution, has studied the apparent connection between fluctuations in the solar constant and the weather. Changes in the solar constant are small and difficult to measure, whereas variations in the thickness of the radio-reflecting "E" layer of the earth's atmosphere are easy to measure with modern radio techniques.

According to a Science Service release, Dr. Abbot believes that approximate predictions of peaks and troughs of Washington temperature can be made a week in advance, provided daily reports of the E layer are obtained from a sufficient number of stations, and if means can be found to anticipate by a few days the date of the next approaching change in the solar constant. "There is," said Dr. Abbot, "a fair hope that such important dates as heavy frosts may become predictable a week in advance from solar observations by this method."

INSTITUTE OF NAVIGATION ORGANIZED

A clearinghouse for information and ideas on navigation has recently been established in the form of the Institute of Navigation. This organization is already international in its membership and is devoted to the promotion of safety by sea and air.

At the first annual meeting, held in October in New York City, air and marine navigators, instructors in navigation, instrument manufacturers, amateur yachtsmen, hobbyists, meteorologists, members of military services, and ship builders exchanged ideas on techniques of navigation and the application of new electronic devices to provide better navigation.

Colin McIntosh, chief navigator of American Airlines, was elected president. The council of 21 members includes representatives of all the various groups of people interested in navigation. Professor Charles H. Smiley, of Brown University, and Professor J. Q. Stewart, of Princeton University, were elected to the council to represent educational activities. Other well-known persons on the council are Captain P. V. H. Weems, USN, Harold Gatty, and George Mixter.

Two types of membership, regular and student, have been established. Persons interested in membership should write to the Institute of Navigation, 1911 Eye St. N. W., Washington, D. C.

COSMOGONICAL IMPLICATIONS OF THE ATOMIC BOMB--III

By FELIX CERNUSCHI, *Guggenheim Fellow at Harvard University*

7. How does the atomic bomb work?

HERE we cannot discuss the many important technological problems formulated and solved during the development of the atomic bomb, but the physical researches and results of the project are worth considering to provide a clear understanding of the functioning of the new weapon.

As was indicated at the end of Section 4, the possibility of a quick explosion of a mass of uranium atoms resided in the chain reaction suggested by Fermi, but at the beginning relevant experimental facts were lacking. Granted that the two particles produced from uranium fission would yield some neutrons before becoming stable nuclei, this is still not enough to make certain a chain reaction will occur, for: 1. Most of the neutrons might escape from the mass of the uranium atoms. 2. Many of them could be captured by uranium nuclei without provoking fission, that is, by *non-fission capture*. 3. The neutrons might be captured by impurities. 4. The neutrons might produce the disruption of other uranium nuclei — these *fission captures* must overcome the losses from the three other processes to produce a chain reaction.

The relative probabilities of these four processes were practically unknown at the start of atomic bomb studies. It was known, however, that U^{235} was disrupted with the greatest probability when hit with thermal neutrons, and that the neutrons resulting from such fission were of high speed, at which non-fission capture is most probable. Consequently, it was not obvious that it was possible to obtain a self-maintaining chain with U^{235}. But it was known that fast neutrons resulting from uranium fission could be slowed down by elastic collisions in certain substances, and it was found later that heavy water, D_20, was excellent for the purpose. Fermi and Szilard proposed graphite (carbon), and this proved to give good results. The substance used to diminish the velocity of neutrons is called a *moderator*.

Uranium or uranium oxide placed in small heaps geometrically distributed in the mass of a moderator (usually in cubic lattice form) would produce fast neutrons which would arrive, with proper spacing of the uranium lumps, at the other lumps with thermal velocities. But by increasing the distances between the lumps sufficiently to slow down the neutrons in this way, the loss of neutrons by escape or absorption in impurities would also be increased.

The number of escaping neutrons is obviously proportional to the surface area of the lattice, and the fission captures are proportional to its volume, other conditions remaining unchanged. Also, the loss of neutrons by non-fission capture depends on the volume of the lattice. The critical size is that for which the production of free neutrons equals their loss by escape and non-fission capture, and to fix this size it was necessary to know the probabilities of the various processes involved.

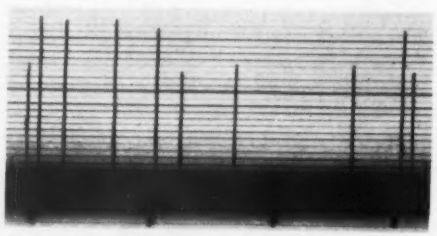
Theory was and is not developed enough to predict these critical values corresponding to the different possible types of lattice. Consequently, it was necessary to perform exhaustive experimental research, and it was found that the critical size of the uranium-graphite lattice could be considerably reduced by enveloping it with some material which reflects the neutrons back; such a reflector is called a *tamper*, and may be composed of graphite and of materials of high density.

Let us define the multiplication factor, k, which plays an important role in experiments in constructing the atomic bomb. Suppose that at the center of the uranium-graphite lattice, which is also called a *pile*, one puts a source of neutrons, for example, a mixture of radium and beryllium. Some of these neutrons will escape from the pile; others will be absorbed in non-fission captures and produce no new neutrons; and others will produce fission and new neutrons. The ratio of these new neutrons to the initial neutrons from the central source is k.

By measuring the number of neutrons inside the pile, first without and then with the uranium lumps, it is possible to determine k for different lattice spacings and shapes, and for different materials. If, in every case, k were found to be smaller than one, a self-continuing chain reaction would be impossible. But if the multiplication factor were greater than one in some cases, the chain reaction and the atomic bomb would become merely matters of engineering, and this proved to be the case.

To increase k it was necessary, among other things, to use highly purified materials in order to reduce non-fission captures by impurities. The maximum permissible amount of impurity was but a few parts per million, both in the uranium and the moderator. The mass production of such pure materials required considerable improvement in chemical and technological methods previously used.

Another way to increase k is by using U^{235}, which is the most effective isotope to produce fission with neutrons, but in nature this isotope is only one part in 140 of uranium samples, and its separation from U^{238} is extremely difficult owing to the small difference of mass. We shall now discuss various refined methods developed for the separation of isotopes, and then turn to consideration of the new transuranic elements, neptunium and plutonium, which played a major role in the success of the atomic bomb.



A photograph of an oscilloscope screen, showing the pulses of the two major energy groups of fragments in the fission of uranium by neutrons. It was made in February, 1939, by Dunning, Booth, and Slack, at Columbia University, shortly after the initial demonstration of the energy release in fission.

8. Methods for isotope separation

THE ISOTOPES of an element have the same number of protons, but a different number of neutrons in the nucleus. They have the same number of valence electrons in the neutral state, and consequently the same chemical properties. It is not generally possible, therefore, to separate isotopes by chemical means; the only feasible processes are those which employ the fact that isotopes differ in mass.

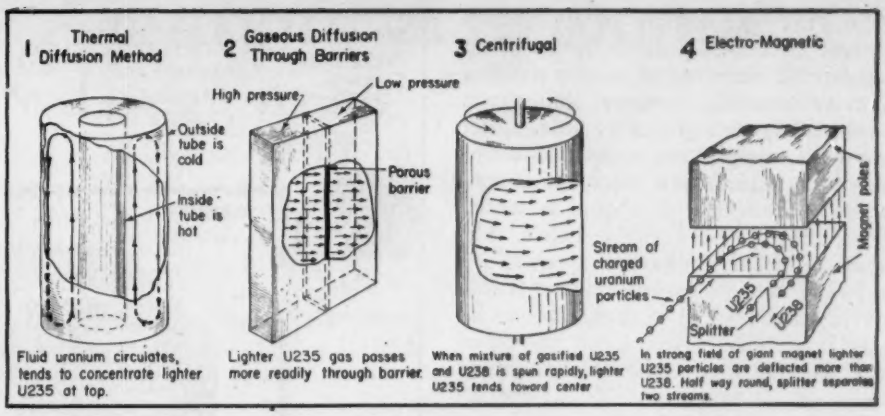
As is well known from elementary kinetic theory of gases, in a mixture of light and heavy particles in equilibrium the average kinetic energy for all particles is the same, $\frac{1}{2}mv^2$. A particle of large mass, therefore, has a smaller velocity than a light particle, and the latter can go through some porous barriers into an evacuated space faster than a heavy particle will go through. Consequently, a gas diffusing through such a barrier will become richer in light particles than it was originally. By repeating such a process several times it is possible to separate the isotopes of a gas. Since uranium is not a gas, it is necessary to use uranium hexafluoride, UF_6, which has a vapor pressure of one atmosphere at a temperature of 56° centigrade. In this case, the ratio of the square root of the masses of heavy to light molecules, upon which their relative velocities depend, is 1.0043. To obtain a useful separation it was found necessary to repeat the diffusion separation at least several hundred times.

Another method of separating isotopes is by using centrifugal force. In the beginning this method failed, but later with a high-speed centrifuge it was possible to get good results. In this case, the separation factor depends on the direct ratio of the masses of the isotopes and not on their square roots as in the diffusion process. Therefore, the centrifugal method is good for the separation of the isotopes of heavy elements.

To procure quantities of the very efficient moderator, heavy water, hydrogen gas was placed in equilibrium with water or water vapor. The hydrogen in the water is catalytically exchanged by deuterons, the water finally containing a concentration of heavy water three or four times greater than the heavy hydrogen in the gas. Another interesting method is that of thermal diffusion, which takes place in a mixed gas under a temperature gradient: the heavy particles tend to concentrate at one end of the gradient and the light particles at the opposite end.

In 1944, a large-scale thermal diffusion plant was functioning at Clinton, Tenn., and a year later a huge gas diffusion plant was successfully operating there. A centrifuge pilot plant was built; another applying distillation methods (extensive distillations are required because the boiling points of light and heavy water differ only slightly) to produce heavy water was built, and another plant used the catalytic exchange method. The Smyth report gives the details and locations of these various plants.

All the methods of isotope separation so far mentioned are called statistical, because they depend on the average behavior of particles in a mass; the methods mentioned do not close the list of possible statistical methods for separating isotopes.


1 Thermal Diffusion Method
2 Gaseous Diffusion Through Barriers
3 Centrifugal
4 Electro-Magnetic
Outside tube is cold
Inside tube is hot
High pressure
Low pressure
Porous barrier
Stream of charged uranium particles
Magnet poles
U235
U238
Splitter
Fluid uranium circulates, tends to concentrate lighter U235 at top.
Lighter U235 gas passes more readily through barrier
When mixture of gasified U235 and U238 is spun rapidly, lighter U235 tends toward center
In strong field of giant magnet lighter U235 particles are deflected more than U238. Half way round, splitter separates two streams.

The fundamental principles involved in the four most successful methods for separating the isotopes of uranium are illustrated here. Reproduced by special permission from "The Atom—New Source of Energy," a reprint in the September, 1945, issues of all McGraw-Hill publications.

Of a quite different nature are electromagnetic processes to separate isotopes. These all make use of atoms in an ionized state, whence they are electrically charged and subject to the influence of electrical and magnetic fields. J. J. Thomson was the first to analyze the rays of positive ions by means of electric and magnetic fields acting in the same direction. He obtained a series of parabolic paths for the particles, each one corresponding to ions of the same mass. Many other workers modified this method of the mass-spectrograph in such a way as to make all the particles of the same mass fall in the neighborhood of a point, instead of along a parabola; and then by placing collectors in the corresponding points for the different masses, they succeeded in obtaining a nearly complete separation of the isotopes of a particular element. Thus, from this point of view, the electromagnetic method is very much superior to all statistical methods. Its disadvantage, however, is that a single piece of apparatus of this type yields very small quantities of material. It is a method of high quality producing low quantity.

By the end of 1941, Dr. E. O. Lawrence, inventor of the cyclotron, well-known type of atom smasher, had borrowed the magnet of the 37-inch cyclotron of the University of California to build a modified mass-spectrograph for large-scale isotope production. The results were excellent, so that the giant magnet of the huge new cyclotron under construction at Berkeley, with a pole diameter of 184 inches, was also borrowed for the same purpose. In 1943, it was decided to build the first plant at Berkeley, consisting of six such units, and by November, 1943, a series of electromagnetic separators was in operation at Clinton. Although the research work was begun later than that on other methods, the Clinton plant was the first to produce large quantities of U^{235}. The material used in this plant, however, was already enriched in U^{235} by the thermal diffusion process.

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9. Two new elements: neptunium and plutonium

ON THE BASIS of the Bohr-Wheeler theory, L. A. Turner and others suggested the possibility that U^{238} under neutron bombardment could be transformed, by two successive beta emissions, into a new element called plutonium, of atomic number 94 and atomic mass 239. This possibility was extensively studied with the cyclotron, and it was found to be true. The reaction involved is:

$$_{92}U^{238} + {}_0n^1 \rightarrow {}_{92}U^{239} \qquad (6)$$

in which the neutrons have slow and intermediate velocities.
After 23 minutes this takes place:

$$_{92}U^{239} \rightarrow {}_{93}Np^{239} + {}_{-1}e^0, \qquad (7)$$

and in 2.3 days:

$$_{93}Np^{239} \rightarrow {}_{94}Pu^{239} + {}_{-1}e^0. \qquad (8)$$

One of the intermediate elements in the reaction is the new neptunium, which has a mean half life of 2.3 days. Plutonium is also a radioactive element of a very long half life and, consequently, practically stable. When plutonium does disintegrate, it releases an alpha particle to become $_{92}U^{235}$, as follows:

$$_{94}Pu^{239} \rightarrow {}_{92}U^{235} + {}_2He^4 \qquad (9)$$

Plutonium is an amazing new element. Under the bombardment of neutrons it may split just as does U^{235}, and by its natural disintegration it produces the extremely valuable U^{235}.

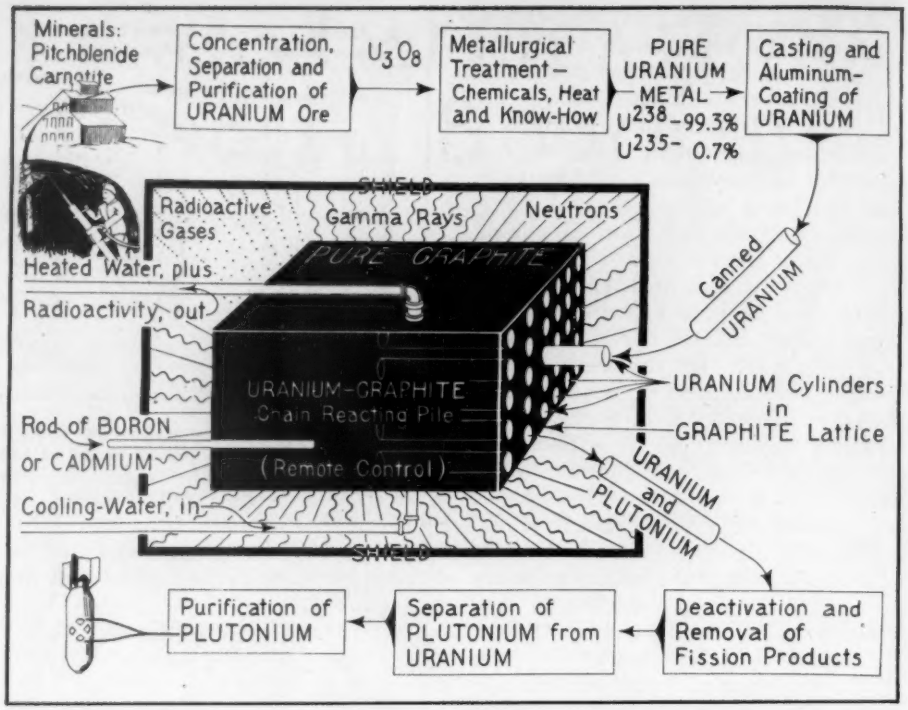
Also, the production of plutonium proves that it is possible to build up semistable elements of atomic number greater than 92, the upper limit given in Mendelyeev's periodic table. Later we shall analyze some possible astronomical implications of this experimental discovery. It should be noted here that Fermi's early belief that some uranium bombarded by neutrons may produce transuranic elements was not a discovery of plutonium, but he has now been justified in his belief that elements of higher atomic number than 92 can exist. It was the intense investigation of his apparently revolutionary experiments which led to the discovery of fission in the first place.

Let us consider the main physical processes involved in the production of plutonium. In the graphite-uranium pile previously considered, suppose that at a definite instant N fast neutrons are produced. Each one of these neutrons, on the average, travels about 2.5 centimeters between collisions with the particles of the moderator, and in a normal pile makes on the average about 200 elastic collisions from the moment of its appearance until it again hits a uranium nucleus. In each elastic collision the neutron loses on the average one sixth of its energy. Therefore, a neutron of one million e.v., for example, reaches a thermal velocity (about 0.025 e.v.) long before completing its path through the moderator. Once thermal velocity is reached, on the average, a neutron does not lose energy in further elastic collisions.

Some of the original N neutrons, however, are used in producing fission of nearby U^{238}, while others are absorbed by U^{238} when their energies are at what are called resonance levels (higher than thermal energy levels). These resonance captures are due to the possible existence of nuclear energy levels within the range of the resonance energies; such captures change U^{238} to U^{239}, then to neptunium and finally plutonium, as already shown. The plutonium, however, is subject to fission, so that when the quantity of plutonium in the pile reaches certain values, the efficiency of the process of producing plutonium decreases due to the fissions it may suffer under the impact of neutrons. When this quantity is reached, the tubes containing uranium are removed from the pile.

Suppose it is assumed that out of the neutrons yielded in each fission, one is used to maintain the chain reaction and the rest are captured by U^{238} to form plutonium. As each fission releases about 200 million e.v., in producing a kilogram per day of plutonium energy is released at the rate of 500,000 to 1,500,000 kilowatts. In the giant plant at Hanford, Wash., the cold waters of the Columbia River offered an excellent means for carrying away this excess energy, and the temperature of the river waters was raised several degrees.

Another advantage of plutonium over the rare isotopes of uranium is that it is a different chemical element and may be separated from uranium by chemical methods instead of by the expensive physical methods which have such low efficiency. Chemical methods used included volatilization, adsorption, solvent extraction, and precipitation, the last being mostly used.



This schematic diagram shows the steps in the production of plutonium. After several processes, some secret, by which the raw ore is converted into uranium, bars of this metal are coated with pure aluminum to protect the uranium from direct contact with the cooling water. The bars are then inserted into the graphite lattice, or pile, until there is just slightly more uranium than the critical amount required to maintain a chain reaction. Some of the initial fissions are caused by cosmic rays. The succeeding reaction is controlled by boron or cadmium throttles. The enormous heat generated is removed by water cooling. After sufficient plutonium has been formed, the bars are removed and the plutonium is separated chemically from the uranium and other products. This drawing is by F. K. Morris, from a design by Dr. Clark Goodman, of Massachusetts Institute of Technology, to illustrate the latter's paper, "Petroleum vs. Plutonium," delivered in November before a meeting of the American Petroleum Institute.

CORRECTIONS

In the November issue, first part of this article, page 3, column 3, line 19, 10^{-13} ergs should be 10^{-12} ergs; page 4, column 1, lines 32-33, 0.932 electron volts should be 0.932 x 10^9 electron volts; second line of caption at the foot of the same page should read "proton entering from the left strikes."

10. Construction of a chain-reacting pile

IT IS IMPORTANT to note that in describing a pile we are really describing the atomic bomb itself. In the case of the piles used in plutonium production, the multiplication factor must be kept under control so that the chain reaction is self-sustaining but so an explosion does not take place. Presumably, the final bomb contains uranium which is very rich in U^{235} and plutonium, with three possible ways for quick fissions to take place: U^{235} is split by thermal neutrons; U^{238} is split by fast neutrons; Pu^{239} is split by thermal neutrons. The similar behavior of U^{235} and Pu^{239} results because each becomes an unstable nucleus of even atomic number and mass when it captures a neutron. Other processes are possible, such as the production of more plutonium from U^{238} resonance captures, as just described, but this is too slow for the actual explosion of the bomb. On the other hand, it is the basis of plutonium manufacture.

When a pile is constructed, the

graphite moderator is cut into bricks and put in layers. At the corners of some of these bricks are put lumps of uranium. In building up the layers a number of slots are left for the insertion of neutron detectors, and also for strips of neutron-absorbing material, such as cadmium or boron steel, to control the functioning of the reaction. In the case of the bomb itself, these cadmium and boron steel strips are the inhibitors which keep the multiplication factor less than one, and which are removed when the bomb is allowed to explode.

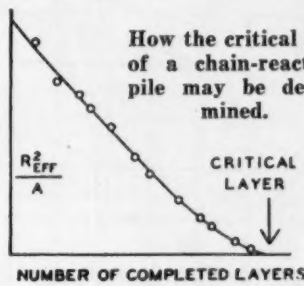
To measure the intensity of the neutrons in a laboratory pile or in a pile for the purpose of producing plutonium, an ionization chamber filled with boron trifluoride is inserted in an appropriate slot. Impacts of neutrons on the boron produce lithium and alpha particles, the latter causing ionization in the chamber which may be directly measured. Another method is to use indium foil, which under the bombardment of neutrons becomes radioactive; the resultant radioactive energy may be measured in an ionization chamber and this gives a measure of the number of neutrons involved in the process.

Evidently, considerable care had to be taken in experiments attempting to establish the critical size of the pile, that is, the size above which the multiplication factor would be more than one. By adding graphite bricks and uranium lumps, and by placing neutron counters inside and outside the lattice, it was possible to determine the multiplication factor for every step in the construction of the pile.

As we have seen previously, the escape of neutrons is proportional to the surface area of the pile—in a spherical pile proportional to R^2, if R is the radius. The activity, A, of the neutrons in the pile, however, increases with the volume. A is therefore proportional to R^3. It is evident that the activity of neutron production will increase much more rapidly than the escape of neutrons as the radius of a spherical pile is increased. In other words, too small a pile cannot be self-maintaining, but a large pile can.

By means of indium foil placed near the center of the pile, we can observe A for each value of R as bricks are added to the pile and its radius is increased. We can then compute the quantity R^2/A (proportional to R^2/R^3). The accompanying diagram shows this quantity plotted on a vertical axis against the number of bricks or layers on a horizontal axis. Because A increases more rapidly than R^2 as bricks are added, we have a steadily decreasing curve. When the multiplication factor becomes a little greater than one, A rapidly tends toward infinity and R^2/A approaches zero. The plotted points represent values observed in the region of safety, and extrapolation shows the critical value of R to be reached where the curve crosses the horizontal axis.

The efficiency of the bomb itself is considerably increased by covering it with a tamper. This has the double function of reflecting back the neutrons and retarding the expansion of the bomb, thus making the explosion more effective.



How the critical size of a chain-reacting pile may be determined.

In disrupting under the impact of neutrons, a kilogram of U^{235} would give up energy equivalent to about 300 tons of TNT. It is possible to construct bombs with a release of energy equivalent to 20,000 tons of TNT, that is to say, as effective for military purposes as 10,000 two-ton bombs.

Nevertheless, these figures are not so very amazing when we realize that only 1/10 of one per cent of the uranium mass is transformed into energy according to the Einstein relation. There is no reason to believe that in the future it will be impossible to find more efficient nuclear reactions, which will transfer a greater per-

(*Continued on page* 17)

Amateur Astronomers

THIS MONTH'S LECTURES

Chicago: A talk entitled "The Second Mile" will be given by J. M. Showalter, president of the Burnham Astronomical Society, at its meeting on Tuesday, January 8th, 8:00 p.m., in the Chicago Academy of Sciences Auditorium. A social hour with refreshments is a feature of the meeting.

Cleveland: "The Great Spiral Nebula in Andromeda" is the subject of a talk by Dr. C. K. Seyfert, of the Warner and Swasey Observatory, before the Cleveland Astronomical Society on Friday, January 18th, at 8:00 p.m. The meeting is at the Warner and Swasey Observatory. On January 10th and 11th, the observatory holds its regular monthly public nights, lecture subject: "The Winter Sky." For reservations call Case School of Applied Science, GArfield 6680.

Geneva, Ill.: The Fox Valley Astronomical Society meets at Aurora College, Aurora, on Tuesday, January 15th, at 8:00 p.m. Dr. Clarence R. Smith, of Aurora College, will give a lecture entitled, "From Backyard Astronomy to the Annals of Fame."

Indianapolis: At the January 6th meeting of the Indiana Astronomical Society, at 2:15 p.m., in Odeon Hall, Paul Richey will speak. His lecture is "All Aboard for 1946."

Madison: At the meeting of the Madison Astronomical Society at 8:00 p.m., Wednesday, January 9th, at Washburn Observatory, Dr. Joel Stebbins, director of the observatory, will speak on "Star Clusters."

New York City: The Amateur Astronomers Association holds its regular monthly meeting at the American Museum of Natural History at 8:00 p.m on Wednesday, January 2nd. Edward Stapowich, of the U. S. Weather Bureau, will speak on "Meteorology." Guest tickets may be obtained by calling ENdicott 2-8500, Ext. 478, or by writing Miss Jane S. Davis, assistant secretary of the society, at the museum, New York 24.

At the meeting of the Junior Astronomy Club on Friday, January 18th, Dr. Paul Hartman will speak on "Atomic Energy." The meeting is at 8:00 p.m., in the American Museum of Natural History.

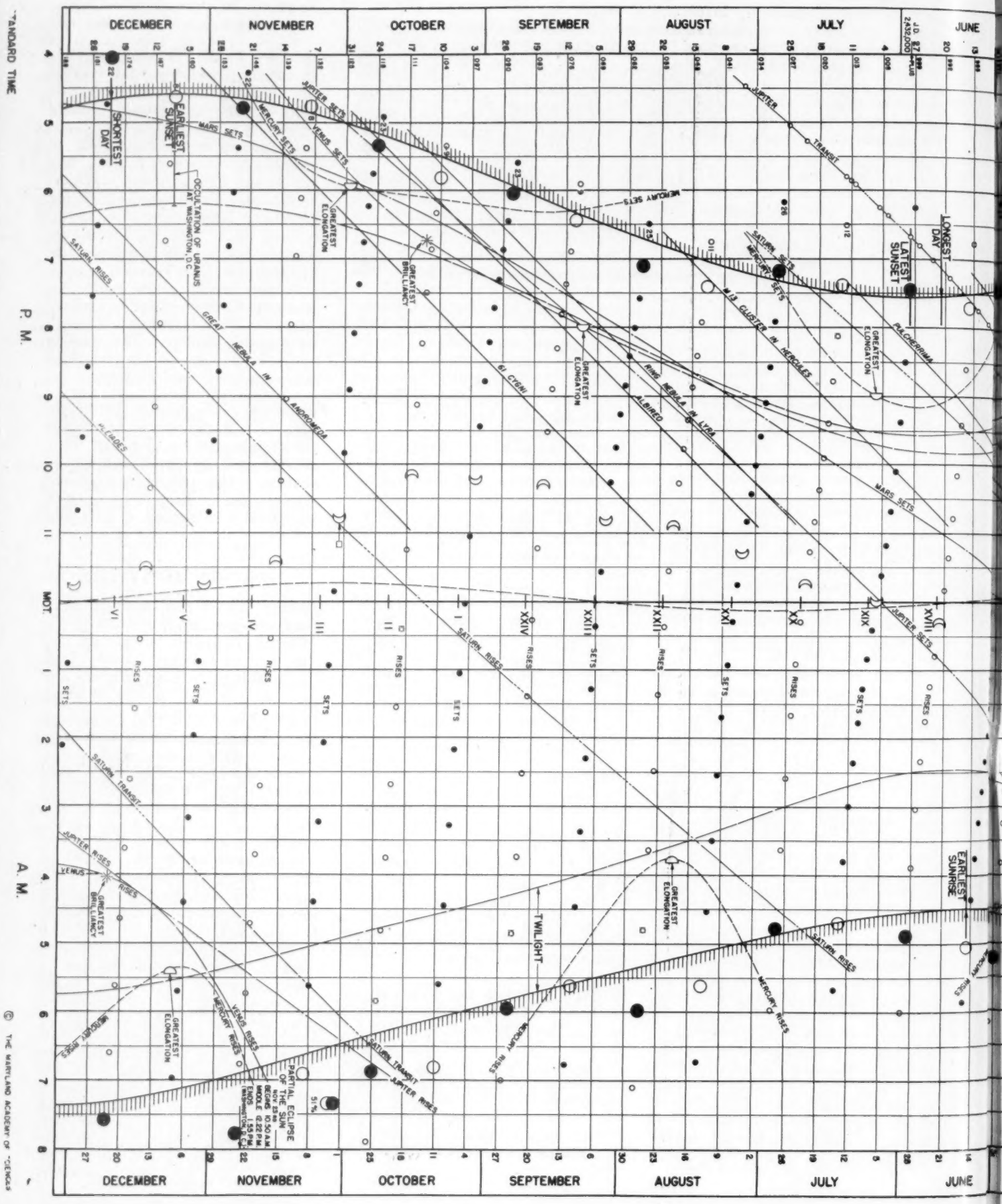
Pittsburgh: The speaker before the Amateur Astronomers Association of Pittsburgh, on January 11th, Friday, will be Dr. Edwin Ebbighausen. His subject is "Galactic Revolution." The meeting is in the Buhl Planetarium at 8:00 p.m.

JANUARY ACTIVITIES

Detroit: The annual business meeting and election of officers of the Detroit Astronomical Society will be held on Sunday, January 13th, at 3:00 p.m., with an informal dinner at the close of the meeting, place to be announced.

Graphic Time Table

PREPARED BY THE MARYLA



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The Graphic Time Table of the Heavens

while still available may be secured without charge directly from the Maryland Academy of Sciences, Pratt Library Building, 400 Cathedral St., Baltimore 1, Md. Blueprints of the original drawing before reproduction are available at cost—50c each—40x27 inches. An edition, in French, for latitude 47° north, may also be obtained.

The Graphic Time Table gives the rising and setting times of the sun, moon, and bright planets; the beginning of morning twilight and the ending of evening twilight; the times when certain stars and other objects of interest transit (cross the celestial meridian); phases of the moon; the equation of time; and other astronomical information. To illustrate by an example: The events of the night of January 3-4 may be found by following the horizontal line for that date across the graph from left to right. The Julian Day number for that evening is 2,431,824. The sun sets at 4:47 p.m. standard time; the moon is one day past new and sets at 5:00 p.m.; Saturn rises at 5:23; Mars rises at 5:32; evening twilight ends at 6:24; the Pleiades cross the meridian at 8:53; the Great Nebula transits at 10:44. The equation of time curve shows that the sun is slow and will not be on the meridian until five minutes after 12 o'clock noon, local time, January 4th. Saturn transits at 12:40 a.m.; Mars transits and Jupiter rises at 2:08 a.m., and so on for the remainder of the night.

The dashes on the sunset and sunrise curves aid interpolation on intermediate days. Roman numerals show sidereal time at midnight. The phases of the moon are indicated by the conventional symbols. Small black circles show moonset for the first half of the lunar month, and small open circles show moonrise from full to new moon. Circles on the Jupiter transit curve indicate nights on which occultations or eclipses of Jupiter's bright moons occur between 7:00 and 10:00 p.m. E.S.T. Small squares on planet curves indicate quadrature, and oppositions are marked by the conventional symbol of two joined circles.

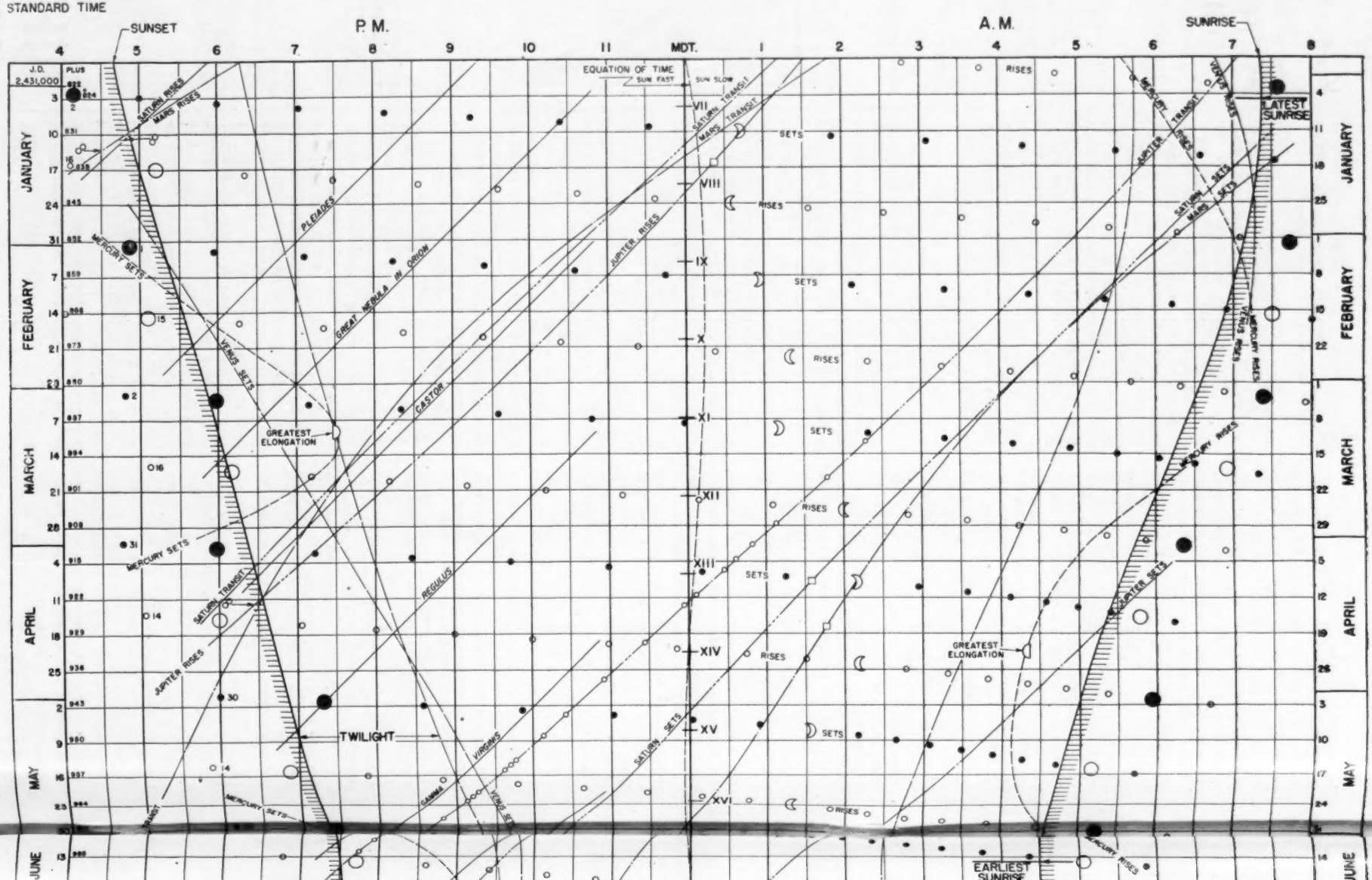
How to Correct for Your Position

As in all almanacs, times of rising and setting of sun, moon, and planets, are absolutely correct for only one point on the earth's surface—for this chart: latitude 40° N. and longitude 90° W. The observer may easily correct for his own position. Latitude differences have comparatively minor effect and may in general be disregarded.

Correction for difference in longitude depends principally on the observer's distance east or west of his standard time meridian, which is always at an even multiple of 15°. Some corrections are tabulated here, in minutes of time:

Atlanta	+38	Denver	0	New Orleans	0
Baltimore	+ 6	Detroit	+32	New York	— 4
Boston	—16	Houston	+22	Pittsburgh	+20
Chicago	—10	Indianapolis	—16	San Fr'cisco	+10
Cincinnati	+38	Los Angeles	— 7	St. Louis	+ 1
Cleveland	+27	Minneapolis	+13	Washington	+ 8

All places with plus correction are west of the standard meridian, and the events will occur later. The usual correction of one hour for each standard time zone must also be made to the Eastern standard times given for lunar eclipses and Jupiter's satellites, and in the Far West slight corrections may be made to times of moonrise and moonset. For times of occultations and solar eclipses, refer to the "American Ephemeris."



of the Heavens - - 1946
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Important McGraw-Hill Books

★

THE ELEMENTS OF ASTRONOMY. New fourth edition

By EDWARD A. FATH, Carleton College. *McGraw-Hill Astronomical Series.* 386 pages, 5¼ x 8¼, 253 illustrations. $3.00

This successful standard text has been revised to include new material accumulated since the publication of the third edition. Many sections have been rewritten in the light of further classroom experience; diameters and distances of planets have been corrected for new values of the solar parallax; in the chapter on practical astronomy the principles of navigation have been rewritten and amplified; the chapter on Other Galaxies has been entirely rewritten; and a new chapter on the structure of the galactic system has been added.

HANDBOOK OF METEOROLOGY

Edited by F. A. BERRY, Jr., Captain, USN; E. BOLLAY, Lieut. Comdr., USNR; and NORMAN R. BEERS, Lieut., USNR. 1116 pages, 5¾ x 8¾, 730 illustrations, $7.50

The most complete work of its kind ever published, this handbook covers all the material usually given to students in comprehensive training programs in meteorology, including mathematics; thermodynamics; physics of the air; radiation, descriptive meteorology; climatology; dynamic meteorology; instruments; codes, maps, and plotting; synoptic meteorology and weather forecasting; oceanography; and hydrometeorology.

METEOROLOGY. With Marine Applications

By WILLIAM L. DONN, Lieut., USNR, U.S. Merchant Marine Academy. In press—ready in January.

A general and descriptive text on meteorology and its marine applications. Gives a thorough groundwork in the observation and theory of the weather elements, and then presents an extended treatment of the hurricane, with attention to modern concepts of air masses and fronts as applied to weather interpretation.

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BOOKS AND THE SKY

ATOMIC ENERGY IN THE COMING ERA

David Dietz, Dodd, Mead & Co., New York, 1945. 184 pages. $2.00.

FORETELLING the future is an art in which cautious men do not usually indulge. It is what David Dietz has attempted in order to fulfill the title, **Atomic Energy in the Coming Era.** His first chapter, "The Era of Atomic Energy," is pure sensationalism which apparently was not written with the rest of the book. Unless the reader has courage to continue beyond this chapter, he might judge the book to be of the pulp-magazine level. This very unfortunate start could be skipped since it is not integrated with the remainder of the volume.

Most of the material, comprising two thirds of the contents, is a carefully written historical treatment of the developments in atomic and nuclear physics up to and including the concepts of energy release in fission. This main section of the book is well worth the careful attention of the non-technical reader. It contains the knowledge essential to the understanding of nuclear processes. It is written interestingly, and the ideas involved are carefully explained so that no technical training is necessary.

After bringing the reader up to date on nuclear physics, Mr. Dietz includes two chapters on "The Atomic Bomb Tested," and "The First Bomb is Dropped." These are rewrites of the early press releases of these two events, including the errors of facts which were later corrected by more accurate reporting. There is nothing new or more accurate in these two chapters than what appeared in all the newspapers of the country directly after the Hiroshima bombing.

Incidentally, the illustrations have positions in the volume having little to do with the text. Even with current paper-saving techniques, an arrangement whereby nine pictures of cyclotrons, Van de Graaff machines and the like are contained in a section describing physical developments in 1895 might have been avoided.

There are actually less than a dozen pages which discuss scientifically the problem of atomic energy. But the bulk of the book, reviewing the historical development of nuclear physics, is highly recommended to the lay reader. It is unfortunate that it is lost behind a misleading title, a sensational beginning, and a rewrite of newspaper accounts for a conclusion.

SANBORN C. BROWN
Massachusetts Institute of Technology

ASTRONOMY—THE SOLAR SYSTEM

Russell, Dugan and Stewart, Ginn and Company, Boston, 1945. Vol. I, Revised Edition. 470 pages. $3.00.

THE REVISION of Russell, Dugan and Stewart's **Astronomy**, for 19 years a bible for both students and astronomers alike, has been needed for several years. Now the first volume, on the solar system, has been brought up to date by Professor Russell; it will be greatly welcomed by everyone interested in astronomy.

Every statement, number, and tabular entry apparently has been checked or improved on the basis of the most recently published research in the field, Professor Russell's unexcelled judgment being available in controversial matters. Although the changes have been made without repaging, except for two extra pages for Pluto that were compensated by revisions before the end of the volume, the advances in the science of the solar system have been well presented. In some instances, however, a longer discussion might be welcomed.

The revisions in this volume represent the progress in solar-system astronomy during the past 19 years. Outstanding are the discovery of Pluto, the identification of ammonia, methane, and carbon dioxide in the atmospheres of the planets, the concomitant increase in understanding of the structure of the planets, radical changes in theory but continued nebulosity as to the exact process of planetary evolution, and finally, much progress in observational data and techniques.

Though solar-system astronomy may be considered by some as a decadent field of endeavor, real progress has been made in almost all phases. Even the sun's parallax has been changed appreciably. New observations and discoveries with respect to the satellites, meteors, interplanetary material, asteroids, and particularly comets, are continuously suggesting new lines of thought and research to increase both one's understanding and bewilderment regarding our local sample of the universe.

It is hoped that a thorough revision of Volume II, Astrophysics and Stellar Astronomy, partially revised in 1938, will soon be forthcoming.

FRED L. WHIPPLE
Harvard College Observatory

NEW BOOKS RECEIVED

TABLES OF SUNRISE, SUNSET, AND TWILIGHT, Supplement to American Ephemeris, 1946, *U. S. Nautical Almanac Office,* 1945, *Supt. of Documents.* 196 pages. 75 cents.

The main tables in this new publication of the Nautical Almanac Office give the local times of sunrise and sunset for each day, and the durations of twilight and daylight for every second day, at each degree of latitude from the equator to 75° north, with auxiliary tables for the conversion of local time to standard time; for interpolation to the exact latitude; for Southern Hemisphere data; for reduction to a particular longitude and year; and for corrections for elevation of the observer, atmospheric conditions, and obstruction of the horizon. There are special graphs for the duration of sunlight and twilight in the polar regions.

This book may be ordered from the Superintendent of Documents, Washington 25, D. C.; cash or money order must accompany order.

ASTRONOMICAL ANECDOTES

CAROLINA BAYS AGAIN—REPLY FROM SASS

THE AUTHOR of the *Saturday Evening Post* article that was condemned in this department in the October and November issues is Herbert Ravenel Sass, of Charleston, S. C. His comment on my comment is given herewith:

I should like to enter a mild protest against certain assumptions of your contributor R.K.M. . . . who seems to say that my article is based upon a partial and incorrect reading of a paper by Professor Douglas Johnson in *The American Scientist*, a quarterly periodical. This is wholly erroneous: I have never seen Professor Johnson's paper. . . . My article was based upon the published studies of various scientists plus my own firsthand observation of the bays.

R.K.M.'s meaning in his October contribution is not entirely clear. When he says, "Now this is as far as the reading and reasoning of the popular writer [myself] took him," he may be referring not specifically to the Johnson paper, which he has just been outlining, but to the whole body of evidence favorable to the meteoric theory of the bays' origin. In that case his statement is equally erroneous, "the reading and reasoning of the popular writer" having included the other theories also. The declared subject of the article, however, was the meteoric theory.

In November, R.K.M. sums up by saying: "Everything about it [my article] is good except the facts." This is an example of loose statement surprising in a scientific man and, I think, does not express R.K.M.'s meaning. What he is questioning is not the article's statement of the facts (which are stated correctly) but its interpretation of the facts.

Actually my article does not give any interpretation on its own authority. It simply puts into readable form, with due development of the very considerable dramatic values involved, an interpretation—the meteoric or comet theory—suggested by certain scientists whose names are given; presenting at the same time certain interesting parallel instances of undoubted meteoric falls in other parts of the world. At the beginning and near the end the article states plainly that this interpretation is denied by other scientists (again names are given) and therefore cannot be regarded as established.

I have great respect for Mr. Waldemar Kaempffert but if R.K.M. represents him correctly as asserting that no scientist of repute considers that the bays could have been made by the meteorites of a comet, then I venture to say that for once Mr. Kaempffert has been a bit too dogmatic. Surely, for instance, Dr. William Schriever, chairman of the department of physics of the University of Oklahoma, is a scientist of repute, and a letter of appreciation from him since the publication of my article shows how earnestly he still maintains the meteoric theory which he, with Dr. F. A. Melton, originally suggested. Before writing my article, I asked the head of the department of geology at our state university, Professor Stephen Taber, for his opinion of the various theories as to the origin of the bays. He replied: "I do not think that any of the writers on this subject has proved his hypothesis. We must reserve judgment and maintain an open mind until more evidence is presented." This scarcely supports R.K.M.'s view that the multiple theory of Professor Johnson has so completely disproved and displaced the meteoric theory that the latter can no longer even be considered.

For myself, I am not a geologist, physicist, or astronomer and I don't know what made the bays. My role in this matter has been simply that of a reporter who felt that the meteoric theory, admittedly only a theory, deserved for several reasons—not all of them scientific—more attention than it has had from the general public. But although acting in this instance only as a reporter, perhaps I have one advantage over some more learned absentee critics—I know the bays not only from what others have written about them but at first hand.

Suppression of other interpretations *is* interpretation. Selection of data is a common procedure among some popular writers. Although Mr. Sass knew there were other explanations, the meteoric was the only one he would talk about. For the purpose of his "interpretation," Mr. Sass ignored the other material. Unless the whole truth, as it is known, is stated, the facts are incorrectly stated. Such tactics should be judged by their effect—what does an otherwise uninformed reader of the article now believe? Since he has been given only one view, and that the wrong one, I still insist, he has been wrongly informed.

It would be interesting to have a comment as of January, 1946, or even of September, 1944, from each of the scientists named in Mr. Sass' presentation, after they had read Professor Douglas Johnson's article and book.

Mr. Sass can be assured that I quoted Mr. Kaempffert correctly as saying, "No geologist [not scientist] of repute considers the markings found as those of a comet," and also Dr. Westgate. I like geologists best in this affair. May I ask if Professor Taber has read Professor Johnson's works, and others that give geological explanations of the origins of the bays? My contention is that any origin, including handmade, is possible, with the one exception of meteoric.

Firsthand knowledge by one who knows neither geology nor meteoric craters is likely not to be very impressive to scientists. I remember that down in Warren County, Ohio, about five miles east of Lebanon, there was the Rock Schoolhouse, named from the great rock that lay near it. By the oldest settler this rock was known at first hand to be a meteorite. Second hand, it was granite, rolled down there by the ice-age glacier, for this is on the edge of the terminal moraine.

The bays are similar in one respect; they are all elliptical—none is circular. Those who insist on the meteoric theory of the moon's craters state that such craters will be circular in almost every instance. Therefore, the Carolina bays are not meteoric craters.

Mr. Sass has been mild, indeed, in his protest. I believe he remains unconvinced, however, and I recommend further reading. We have much to undo as a result of his article. There are too many purely observational features of the bays, brought out by Professor Johnson, but ignored by Mr. Sass, to justify his exclusion of other theories and the dramatization of the one which, in my opinion, as well as that of the overwhelming majority of those who are really capable of judging, is the only one that has no merit.

R. K. M.

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THE BOOK CORNER

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OBSERVER'S PAGE

Greenwich civil time is used unless otherwise noted.

New Comet Discovered by Two Amateurs

ON THANKSGIVING EVENING Clarence Friend, well-known Escondido, Cal., amateur, observed a new comet. He immediately telegraphed his discovery to Harvard College Observatory, clearinghouse for such information in the Western Hemisphere. The comet, of the 7th magnitude, was at right ascension 16 hours 20 minutes, and declination 30 degrees north.

In a letter subsequently written to Dr. Leland E. Cunningham, who is at present at Aberdeen Proving Ground, Mr. Friend says: "I picked up the comet in the constellation of Hercules after less than five minutes of sweeping, and an odd thing about it is that I picked it up within less than three degrees from the last comet that I discovered. I knew as soon as it came into the field that it was a comet." Later, Mr. Friend wrote that he was able to observe the comet with field glasses on November 30th, but that it was then just beyond the reach of the unaided eye.

Two nights after discovery, on November 24th, Leslie C. Peltier, of Delphos, Ohio, independently discovered the same comet, and wired its position as $16^h\ 25^m$, $+26°$. In the meantime, Harvard had wired several observatories for confirming observations, and the comet was well observed during the last week of November and the very early part of December. The Harvard clearinghouse received position reports from the Warner and Swasey Observatory, East Cleveland, the observatory at Smith College, Lowell Observatory, and other places. Several Harvard plates were also taken. H. L. Giclas, at Lowell, described the comet on November 29th as of the 6th magnitude, diffuse, with a nucleus, and a tail less than one degree long.

From these observations, Dr. Cunningham computed parabolic elements of the comet's orbit, and together with an ephemeris of predicted apparent positions, these were published on Harvard Announcement Card 729. The comet was to pass perihelion (point in its orbit nearest to the sun) on December 17th, at which time its distance from the sun was about one fifth of an astronomical unit, or some 18 million miles. The inclination of the orbit to the plane of the ecliptic is close to 50 degrees. The longitude of the ascending node is 325° 24′ and the longitude of perihelion is 216° 43′.

The ephemeris showed the comet to be increasing the southward motion indicated by the Friend-Peltier original positions. It moved down from Hercules and Corona, through Ophiuchus into Sagittarius. The predicted positions showed that while the comet would probably increase in brightness until it had passed perihelion, it would be too close to the sun for observation. And this unfortunate condition was certain to hold throughout January and February. Meanwhile, as the comet recedes from the sun, its brightness will fall rapidly, from about the 8th magnitude in early January to the 12th magnitude by February, and 14th or 15th magnitude by the end of that month.

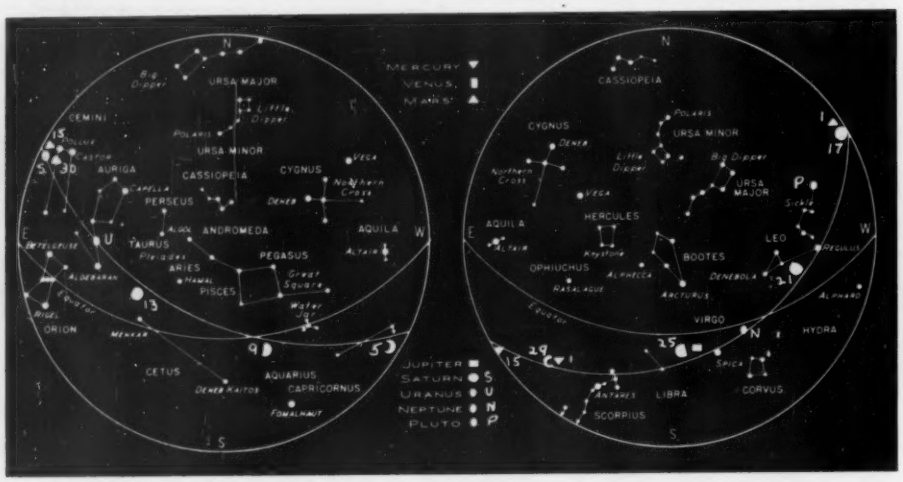
Dr. Cunningham kindly provided us with a complete ephemeris to March 1st, but in the accompanying letter, dated December 8th, he says:

"I doubt that the comet can be observed in the Northern Hemisphere after December 15th, and nowhere on earth after Christmas, until possibly sometime late next spring with the very largest telescopes. It remains extraordinarily close to the sun for nearly three months. I doubt that I have ever seen such an unusual case."

As this goes to press, it is not possible to present all the tabular information supplied by Dr. Cunningham, but the data below may be of interest. The dates selected are December 7, 15, 23, 31, January 8, 16, 24, February 5, 17, March 1. On these dates the comet had or will have: right ascension 16:20, 16:33, 17:55, 19:08, 19:57, 20:31, 20:57, 21:27, 21:50, 22:09; declination (all south) in degrees 0.9, 22.4, 33.6, 32.5, 29.3, 26.0, 22.7, 18.9, 15.5, 12.5; distance from earth in astronomical units 0.76, 0.91, 1.20, 1.43, 1.65, 1.85, 2.06, 2.30, 2.53, 2.73; distance from sun in astronomical units 0.41, 0.21, 0.29, 0.51, 0.71, 0.90, 1.08, 1.32, 1.55, 1.76; estimated magnitude (4th-power law) 5.0, 2.5, 4.4, 7.3, 9.0, 10.3, 11.3, 12.4, 13.3 14.1; angular distance from sun in sky in degrees 23, 13, 10, 11, 13, 11, 9, 5, 4, 10.

For example, on January 16th, the respective values are: $20^h\ 31^m$, $-26°.0$, 1.85 A. U., 0.90 A. U., mag. 10.3, 11 degrees from sun.

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 7:30 a.m. local time on the 7th of the month, and at 6:30 a.m. on the 23rd. At the left is the sky for 5:30 p.m. on the 7th and 4:30 p.m. on the 23rd. The moon is shown for certain dates by symbols which give roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury is still very favorably placed for observation before sunrise during the early part of January. By the end of the month, however, it will be too close to the sun to be seen. Mercury will be in close conjunction with the moon on January 1st, at 15:08 GCT.

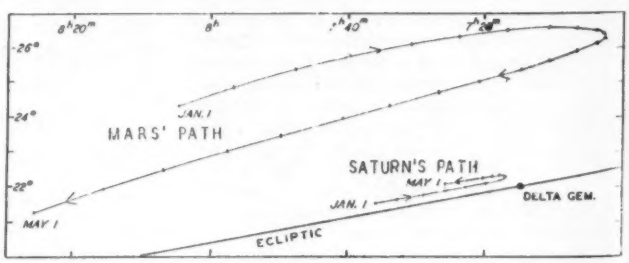
Venus will be in conjunction with the moon on January 2nd, at 21:31, but both objects will be very near the sun, as new moon occurs 15 hours later. Venus reaches superior conjunction on February 1st.

Mars is visible all night, reaching opposition on the 14th, and is in conjunction with Saturn on the 22nd.

Jupiter is in Virgo, near Spica. It rises about midnight.

Saturn is in opposition on the 12th; compare its rate of retrograde motion with that of Mars, which is west of Saturn from January 22nd to March 19th. (See the diagram below.)

Uranus is in Taurus; **Neptune** is in Virgo; **Pluto** is in Cancer.



The paths of Mars and Saturn for the first four months of 1946. Mars is plotted at five-day intervals; Saturn, at 10-day intervals.

OCCULTATION PREDICTIONS FOR JANUARY

13-14 **85 H¹ Tauri** 6.0, 4:17.3 +18-36.9, 10, +78° 0° Im: A 0:34.9 —2.0 +0.3 95°; B 0:34.6 —1.6 +0.7 85°; C 0:24.9 —2.1 +0.2 100°; D 0:23.7 —1.6 +1.0 83°; E 0:03.5 —1.1 +1.4 76°; F 23:43.2 —1.2 +1.0 89°; H 23:42.3 +0.1 +1.9 45°.

13-14 **234 B Tauri** 6.0, 4:21.8 +18-55.2, 10, +76° —1° Im: A 3:19.5 —1.9 —2.3 118°; B 3:12.3 —1.7 —1.4 105°; C 3:21.1 .... 136°; D 3:03.9 —2.0 —1.4 109°; E 2:42.1 —2.5 —1.0 111°; G 2:15.6 —0.8 +1.9 51°; H 1:45.3 —1.1 +1.3 78°; I 2:06.8 —0.5 +2.2 44°.

13-14 **Epsilon Tauri** 3.6, 4:25.5 +19-03.7, 10, +83° +4° Im: A 5:26.1 .... 143°; B 5:14.4 —0.8 —3.0 126°; D 5:16.1 .... 140°; G 4:06.4 —1.5 +0.4 85°; I 3:51.8 —1.4 +0.8 84°.

14-15 **o Tauri** 4.8, 5:24.4 +21-53.7, 11, +80° +7° Im: A 4:00.0 —1.8 —4.0 139°; B 3:49.0 —1.8 —2.2 123°; D 3:42.5 —2.0 —2.7 130°; E 3:25.9 —3.1 —4.3 141°; G 2:45.2 —0.9 +1.5 73°; H 2:21.9 —1.4 +0.6 104°; I 2:36.0 —0.6 +1.8 67°.

14-15 **BD +22° 925** 6.5, 5:27.5 +22-25.3, 11, +48° —15° Im: A 5:40.3 —1.7 +1.7 33°; B 5:47.3 .... 13°; C 5:28.8 —1.7 +0.7 52°; D 5:31.0 —1.7 +2.0 32°; E 5:04.9 —1.8 +1.3 51°; F 4:43.6 —2.4 +0.1 85°; H 4:10.2 —1.1 +2.5 42°.

19-20 **46 Leonis** 5.7, 10:29.3 +14-24.9, 16, +47° —28° Em: C 7:11.8 —0.6 —4.0 352°; E 6:54.1 —1.2 —2.4 336°; F 6:54.8 —1.9 —0.3 292°; H 6:22.4 —1.0 —0.3 310°.

For selected occultations (visible at three or more stations in the U. S. and Canada under fairly favorable conditions), these predictions give: evening-morning date, star name, magnitude, right ascension in hours and minutes and declination in degrees and minutes, moon's age in days, limiting parallels of latitude, immersion or emersion; standard station designation, G.C.T., **a** and **b** quantities in minutes, position angle; the same data for each standard station westward.

Longitudes and latitudes of standard stations are:

A +72°.5, +42°.5	**B** +73°.6, +45°.6
C +77°.1, +38°.9	**D** +79°.4, +43°.7
E +91°.0, +40°.0	**F** +98°.0, +30°.0
G +114°.0, +50°.9	**H** +120°.0, +36°.0
I +123°.1 +49°.5	

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Greenwich civil time to your own standard time.

For additional occultations consult the **American Ephemeris and Nautical Almanac** and the British **Nautical Almanac**, from which these predictions are taken. Texas predictions were computed by E. W. Woolard and Paul Herget.

SIX ECLIPSES THIS YEAR

FOUR ECLIPSES of the sun and two of the moon will occur in 1946. On January 3rd, in the South Pacific, there will be a partial solar eclipse, with 55 per cent of the sun's diameter obscured at maximum eclipse. This is the solar eclipse which must occur at this "eclipse season," and is thereby related to the eclipse of the moon in December, 1945.

The eclipse season centered on the full moon of June 14th accounts for three more obscurations. A partial solar eclipse occurs in the South Pacific on May 30th, maximum, 89 per cent. Then there is a total eclipse of the moon on June 14th, invisible in North America, but visible mostly in the eastern hemisphere. Finally, on June 29th, the Arctic regions, including Greenland, experience an 18 per cent solar eclipse.

Practically all of North America will view a partial eclipse of the sun on November 23rd, with greatest magnitude, 0.776, occurring in the Atlantic Ocean at 45° west, 63° north. But the total eclipse of the moon on December 8, 1946, will be invisible in the United States.

GREENWICH CIVIL TIME (GCT)

TIMES used on the Observer's Page are Greenwich civil or universal time, unless otherwise noted. This is 24-hour-time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the GCT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

ANOTHER NEW COMET

As we go to press, a new comet is reported discovered by the South African observer, D. du Toit. The comet was of the 7th magnitude, located at 15ʰ 8ᵐ, —65°, on December 11th; daily motion 30ᵐ east and 73′ north.

PHASES OF THE MOON

New moon .....January 3, 12:30
First quarter .....January 10, 20:27
Full moon .....January 17, 14:46
Last quarter .....January 25, 5:00

LORAN TABLES AND CHARTS

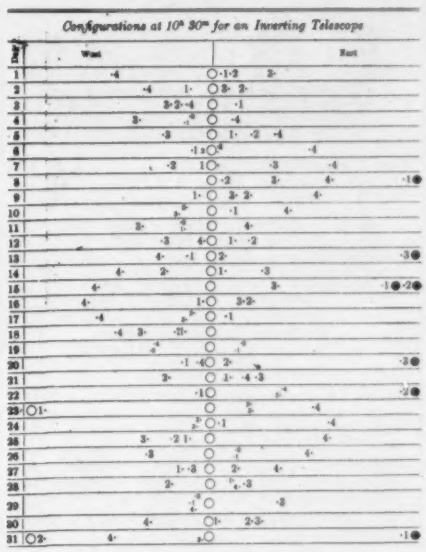
(*Continued from page 6*)

son of winter and summer observations shows the E layer to be somewhat higher in the summertime, but the small shift in this layer is not enough to cause changes in the predicted sky-wave corrections.

The possibility of measuring arcs of 300 to 500 miles over water with a precision of 500 feet suggests the use of loran and other electronic devices as new tools for triangulation. In the laboratory, considerably higher precision has already been obtained, and it is probable that in the near future long over-water arcs that cannot be bridged by any optical means will be measured directly to a few feet. Then the deflection of the vertical on isolated islands will be known accurately, and more information about the subsurface structure of the oceans can be obtained. The application of electrical devices to navigation and surveying opens up a whole new field of research and usefulness.

JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below for the GCT given. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. Reproduced from the **American Ephemeris and Nautical Almanac.**



MINIMA OF ALGOL

Jan. 3, 9:03; 6, 5:52; 9, 2:41; 11, 23:30; 14, 20:19; 17, 17:07; 20, 13:56; 23, 10:45; 26, 7:34; 29, 4:23; Feb. 1, 1:12.

COSMOGONICAL IMPLICATIONS OF THE ATOMIC BOMB

(*Continued from page 11*)

centage of matter into energy, and which will use more abundant elements. There is the possibility, also, of producing chain reactions of the type proposed by H. A. Bethe[19] to explain the source of solar radiation—the *carbon cycle* in which four hydrogen nuclei are converted into one helium nucleus, using carbon as a catalyst, with the release of about 26 million electron volts of energy. In this reaction, 7/10 of one per cent of the mass of each hydrogen nucleus is transformed into energy. This is at about seven times the rate of energy release per mass unit in uranium fission. The carbon cycle, however, requires six steps instead of one.

(*To be continued*)

BIBLIOGRAPHY

19. H. A. Bethe, *Physical Review*, *55*, 434, 1939.

The INDEX for Volume IV

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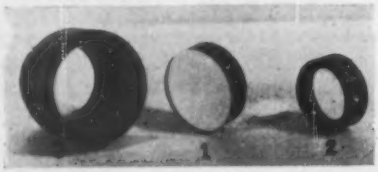

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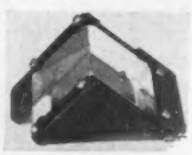

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GLEANINGS FOR A.T.M.s

Experiences With Cassegrainians

IN THE latter part of 1943, I decided to construct an 8-inch Cassegrainian, to be used principally for planetary and lunar observations, also for photography at the secondary focus without further amplification. Of course, time, cost, and available materials had to be taken into consideration. The result was well worth while and my record book of observations shows that I have used this Cass far more than any of my other scopes in previous years.

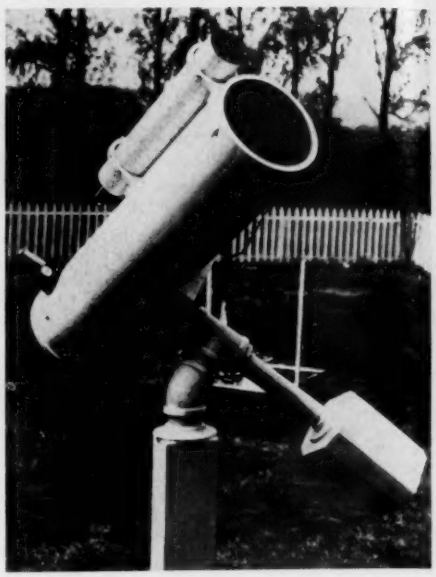
Several years ago I constructed a small 4-inch f/4 Cassegrainian which, while not perfect, was very convenient to use and powerful for its size. Lessons learned from this instrument made the construction of the larger compound scope go rather well and with far less difficulty than I had anticipated.

The 8-inch pyrex mirror is of 42 inches focal length, or a little over f/5, and is 75 per cent corrected. The secondary mirror, of 1.9 inches aperture, is made of spectacle crown and has a spherical curve. This combination of curves is in accordance with Kirkham and Dall's formula; it gives beautiful definition and just about reaches the limit of resolution for this aperture. The convex secondary is a 5x amplifier, giving an equivalent focal length of 210 inches to the combination, or about f/26. This rather long ratio has proven excellent for photography, doubles, lunar and planetary work. The field of view is perfectly sharp and usable over its entirety, regardless of what type eyepiece is used. Medium and high powers are easily obtained with standard sizes.

My home is in the country, far from city lights, and high powers can often be used advantageously; my favorites for visual work are 278x and 420x eyepieces, and 762x for closeup sketches of lunar detail. This is supplied by a 7 mm. orthoscopic eyepiece which has an apparent field of 60 degrees. Even small Coddington eyepieces are sharp over the entire field, although some curvature is present with this type. I also use modified Coddingtons that I have made. These have a much larger and flatter field but less eye clearance.

The primary mirror is not perforated, an optical flat good to 1/10 wave reflecting the rays to the side of the tube just above the primary.

The large mirror was fine ground with #2600 B.& L. emery for an hour, then Barnesite was used as the polishing agent on a hard pitch and rosin lap, which was cold-pressed often. As a result, a good polish was obtained in 4½ hours. Fairly short, straight, circular, and spiral strokes caused the figure to end up a slightly oblate spheroid which was soon brought to a sphere. A few minutes' work with a slow spiral stroke, gradually working from center over center to nearly four inches off center and back again, gave a smooth, accurate correction of nearly 75 per cent on the second test. Very little pressure was used while correcting. I do not know of anyone using a spiral stroke for parabolizing, but with me it works better than standard strokes.



The 8-inch Cassegrainian telescope, f/5—26, described by Walter W. Leight in this article. He also built the 4-inch Cass pictured on the front cover this month.

The following evening, I decided to make a focogram of the curve. One glance at the mirror showed me I now had an oblate spheroid! After getting control of myself, I refigured the mirror, first getting a good sphere, then very slowly correcting as before. I then tested every few minutes for several hours. Result: same as before—the 75 per cent correction gradually slipping back to an oblate spheroid. I then overcorrected a little and it dropped back to a perfect sphere. Next, I overcorrected considerably and it dropped back to the 75 per

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cent correction I had been aiming for. A diffraction edge was just visible and the contour and surface quality were smooth. I put the mirror away for two weeks, then tested again. There was no visible change, so I had it aluminized. Fortunately, the curve has remained at proper correction for more than a year, so the difficulty must have been in the annealing of the pyrex blank. The temperature in our basement did not vary more than 2° F. during the polishing period. However, the rough and medium grinding were done outside in the shade.

A word of caution about aluminizing: Be sure to specify that your mirrors be cleaned only with liquids and cotton; otherwise, mild abrasives may be used and the figure altered considerably. This is important in a Newtonian and doubly so with compound instruments.

The convex secondary was made of spectacle crown ¼-inch thick when finished. It was first ground and polished flat on both sides, also made parallel to a few minutes of arc. It required only one evening to grind, polish, and figure the secondary. I used a medium stroke and a hard lap, thus keeping it spherical. It was tested through the back as if it were concave, although not much could be seen.

The tube is of ¼-inch fiberboard, 10½ x 38 inches, which I shellacked inside and out until it became rigid. Then the inside was painted flat black and the outside flat white and ivory. The mirror cell is built up from rings of ¾-inch plywood. There is also a reinforcement ring of wood at the open end. The cradle and finder brackets are also made of ¾-inch plywood. The finder tube is cut from 4-inch smoke pipe and the 3¼-inch objective, which works at f/7.7, gives fair definition up to 125x, although for finder purposes I use 17x and 25x.

This latter finder eyepiece is equipped with a reticle on which I have etched small circles to represent the field covered with various eyepieces used on the Cassegrainian. The magnification is also etched at the bottom of each circle. Thus, it is very easy to get an object in the field of view at any power, and this is a big improvement over the crosshair type of reticle. The etched circles are filled with white titanium dioxide and sodium silicate and can be illuminated at night from the side by using a small flashlight.

The mounting is made from large 3-inch inside diameter pipe fittings, the tapered threads acting as bearings. The bearing surfaces measure nearly four inches in diameter. The complete set of galvanized fittings cost about 12 dollars. Good threads are needed, of course, the last turn just before they tighten being used. Heavy auto grease protects the threads from weather. The counterweight is built up of wood, and the pier is a 6 x 6 post six feet long—3½ feet above ground. No concrete was used, but it would be an improvement. However, the mounting is very steady with all usable powers, even in a stiff breeze. Larger diameter fittings could be used if desired, as the bearing size would be still greater.

Two brass wing nuts hold the telescope cradle on the pipe flange; two ½-inch diameter bolts extend out from the cradle. The total weight of the entire instrument, finder, eyepieces, cradle and all, is just 21 pounds, and my wife liked the appearance so much we keep it in the dining room, something I could never get away with if it were a Newtonian of the same equivalent focus (17½ feet)!

The performance has been excellent. Star images are small and have diffraction rings very much like those in a long-focus refractor. Lunar detail seems endless on good nights, and craterlets less

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than a mile across are visible. Tiny cracks and hills appear during seconds of exceptionally fine seeing. At least three or four craterlets are visible in Plato and 40 or more in Clavius.

As for the planets, Venus has a crescent nearly 1/16 of an inch in diameter at the secondary focus, which image I photograph in ¼ second or less on fast panchromatic film, then enlarge the image to one inch or more. Saturn's rings and Jupiter's belts have also been photographed. Visually, Jupiter shows much cloud detail and all four satellite shadows are seen in transit; at high magnification the disks of the satellites can be identified by their differences in size. Cassini's division in Saturn's rings can be seen all the way around; traces of Encke's division appear and the crepe ring is faintly visible.

The double-double system of Epsilon Lyrae is clearly separated, the four components and their diffraction rings clear at all powers from 140x to 762x.

The only disadvantage seems to be the fact that 140 is the lowest practical power to use. The large finder is best for wide clusters, the Milky Way, and nebulae.

Recently, I made a 4-inch f/3 Cassegrainian amplified 5x to f/15 or 60 inches effective focal length. It has a small fork-type mounting with a 2-inch bronze bearing. (See the front-cover picture.) Magnifications from 40x to 300x are worth using. There are only 9½ inches between primary and secondary, and the overall length of the scope is 12 inches. It fits in a small plywood case and should be very useful for trips to the shore and mountains. The 0.9-inch aperture and 7-inch focus of the finder are usable at 56x, a power obtained with a ⅛-inch solid ocular. Saturn's rings and two belts on Jupiter are clearly visible. The finder is tubeless, making use of two holes in the main tube in line with the objective and prism. This arrangement eliminates brackets and tube, and facilitates transfer of the eye from finder to eyepiece.

I do not perforate my primary mirrors because I do not wish to weaken the glass. Also, I see little advantage in doing so since the perforated type is nearly always equipped with a prism to reflect the image to the side after it passes through the primary mirror. Otherwise a very high mounting is needed, not to mention strong neck muscles. I make sure the supports for the flat are in direct line with the supports of the secondary mirror.

A 12.5-inch f/4 Cassegrainian is now under way, probably of 250 inches effective focal length. This type of compound is for the writer only slightly harder to construct than a good Newtonian of the same aperture. This is largely due to the spherical secondary and partially corrected primary. The Ronchi test is very useful for checking the general sweep of the curves. All tendency toward turned edge or overcorrection must be avoided. The surfaces must be perfectly smooth as seen under test. Collimation of the finished instrument must be very good.

A perfectly round pinhole 0.004-inch diameter was used with a 20-watt frosted bulb for testing and proved very sensitive. The pinhole was made in shim brass which was thinned down to about 0.001-inch thickness. A hardened steel needle was ground on a #500 diamond wheel until it had a perfect point at 100x through a microscope. This was gently tapped through the shim brass and rotated, then the burr was smoothed off and the needle inserted and rotated from the opposite side. A slit, 0.001 inch wide was also used. This was made by silver and copper plating a small piece of optically flat glass and cutting the slit with a needle that had been worn in to cut a line 0.001 inch wide without scratching the glass.

It is a very great satisfaction to view God's universe through a powerful and compact reflector that one has made with his own hands.

WALTER W. LEIGHT
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PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium, 81st Street and Central Park West, New York City, and of the Buhl Planetarium, Federal and West Ohio Streets, Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *January*, WINTER STARS. (See page 3.)

This month visitors to the planetarium have an opportunity to renew their acquaintance with the winter constellations, of such outstanding beauty and interest. Simple methods are shown for locating the stars of Orion, Taurus, and Canis Major, and the other bright stars which stud the sparkling skies of winter. Ancient constellation pictures appear in the planetarium heavens, and we find that some of these old figures are helpful devices for remembering the positions of stars.

★ **THE HAYDEN PLANETARIUM** presents in *January*, STARS OF A WINTER'S NIGHT. (See page 3.)

In *February*, OUTPOSTS OF THE HEAVENS. We explore this month, in the superb rocket ship of the scientific imagination, the visible universe stretching out from the earth 500 million light-years in all directions. Millions of galaxies come into view, like gigantic celestial pinwheels blazing with billions of suns. Are these parts of an infinite universe, or does the universe come abruptly somewhere to an end? Is space curved or straight? What do the greatest scientists reply in answer to these questions?

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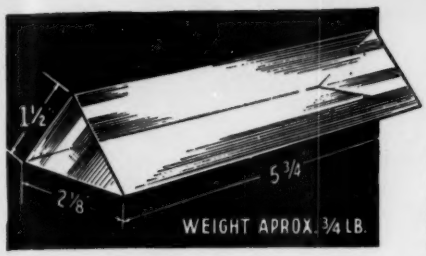

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6164-Y*	26	104	.80
6165-Y	27	185	1.00
6166-Y	29	54	1.25
6168-Y	29	76	1.25
6169-Y	31	122	1.50
6171-Y	32	171	1.00
6173-Y*	34	65	1.00
6176-Y*	38	131	1.00
6177-Y*	39	63	1.10
6178-Y*	45	189	1.50
6179-Y*	46	78	1.25

*ASTERISKED ITEMS are uncemented, but FREE cement and Directions included with uncemented sets.

USES:—Use these Lenses for making Projecting Lenses, Low Power Microscope Objectives, corrected Magnifiers, substitute enlarging Lenses, Eye-Piece Lenses, Macro-photography, Gadgets, Optical Instruments, etc., etc.

CLEANING BRUSH SET . . . For Lenses, Optical instruments, etc. Perfect quality—12 inch Flexible Plastic handle, hollow circular const. Range from stiff to very soft. 4 Brushes to set.
Stock #504-Y—(Reg. $6.00 value) ..... Price $1.00

PRISMS:

If you mount right angle Prism in front of Camera Lens and point camera straight ahead, you can take shot to left or right side without subject's knowledge. Technique successfully used by famous Press Photographers.

Stock No.	Type	Base Width	Base Length	Price
3040-Y	Right Angle	33 mms.	23 mms.	$1.00
3042-Y	Right Angle	41 mms.	40 mms.	1.00
3045-Y	Right Angle	70 mms.	168 mms.	8.00
3001-Y	Lens Surface	20 mms.	14 mms.	2.00
3006-Y	Porro-Abbe	9 mms.	9 mms.	.25
3009-Y	Porro	52 mms.	25 mms.	1.00
3010-Y	Porro	43 mms.	21 mms.	.50
3016-Y	Pentagon	45 mms.	22 mms.	.75
3029-Y	Dove	16 mms.	65 mms.	1.25
3036-Y	80 Degree Roof	60 mms.	36 mms.	4.00
6136-Y	Rhomboid	20 mms.	17 mms.	.50
3049-Y	Right Angle	69 mms.	167 mms.	10.00
3047-Y	Right Angle	53 mms.	103 mms.	4.00
3038-Y	Roof Prism	18 mms.	34 mms.	2.50

TANK PERISCOPE

Complete Set Mounted Components

Rugged, strong, originally constructed for U. S. Tank Corps. Consists of 2 fine Periscope Mirrors mounted in metal and plastic. Perfect condition. Only plywood body frame is required to finish this exceptional Periscope. First surface mirror is well protected by glass windows.

Set weighs 2¾ lbs. Overall length of mount 6⅛", width 2⅛". Would normally retail at $40 to $50.

Stock #700-Y ..... $3.00 Complete Set Postpaid
TWO SETS (4 UNITS) ..... SPECIAL $5.50 Postpaid

ORDER BY SET OR STOCK NO. • SATISFACTION GUARANTEED • IMMEDIATE DELIVERY

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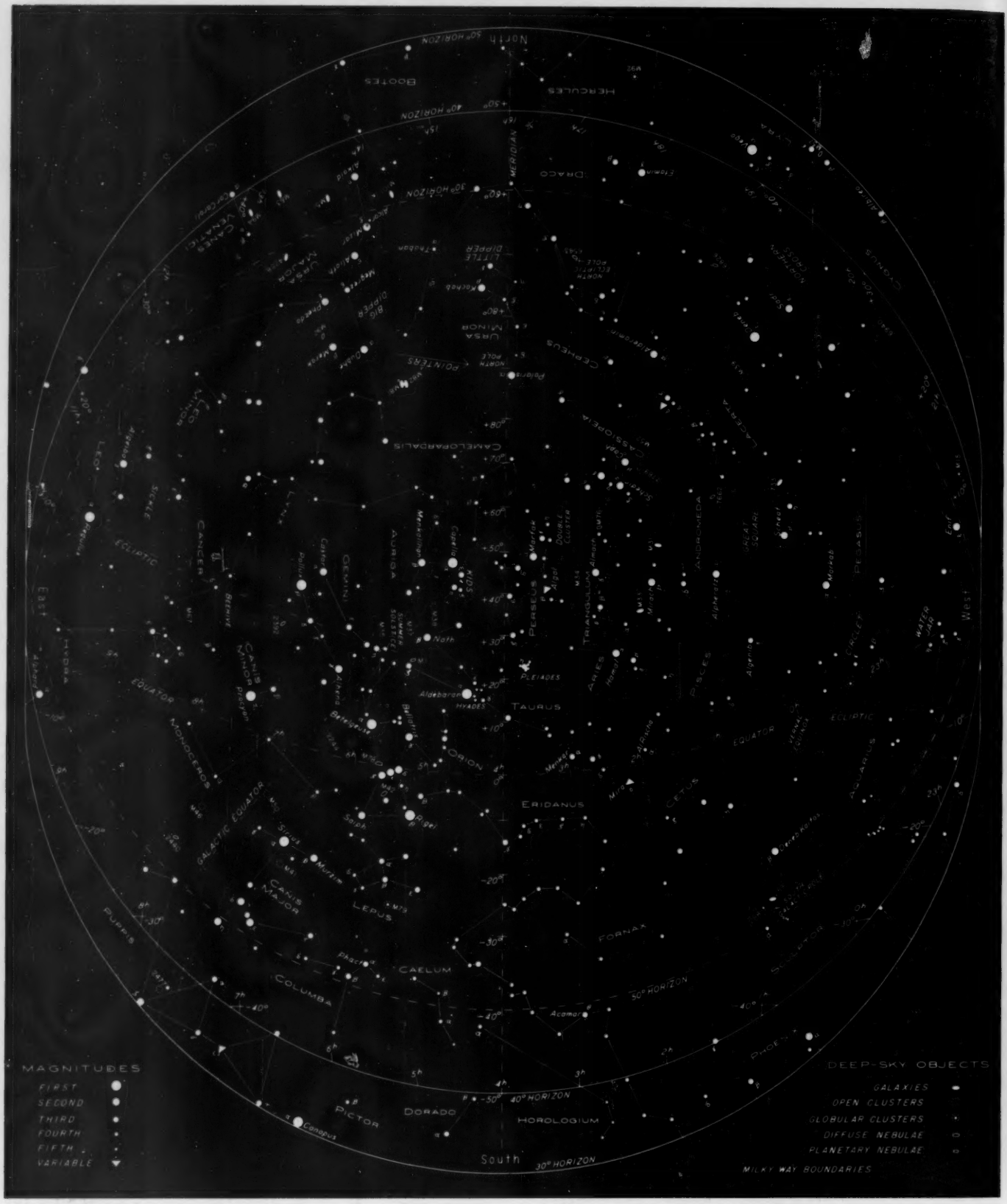


DEEP-SKY WONDERS

AMATEURS are invited this month to find one each of five major types of deep-sky marvels. Numbers in parentheses are the Norton designations.

Orion. NGC 2022 (34^4), $5^h\ 39^m$, +9° 04′; planetary. Small (22 x 17 seconds), faint gray oval. If this is too difficult for your telescope, try M1, the Crab, in Taurus between Zeta and Beta, near Zeta. NGC 2194 (24^8), $6^h\ 08^m.2$, +12° 50′; small cluster of 100 stars. In giant's club-holding hand. M43, $5^h\ 31^m$, —5° 20′; nebulosity; small, mitten-shaped, near Fish-Mouth of M42, the Great Nebula.

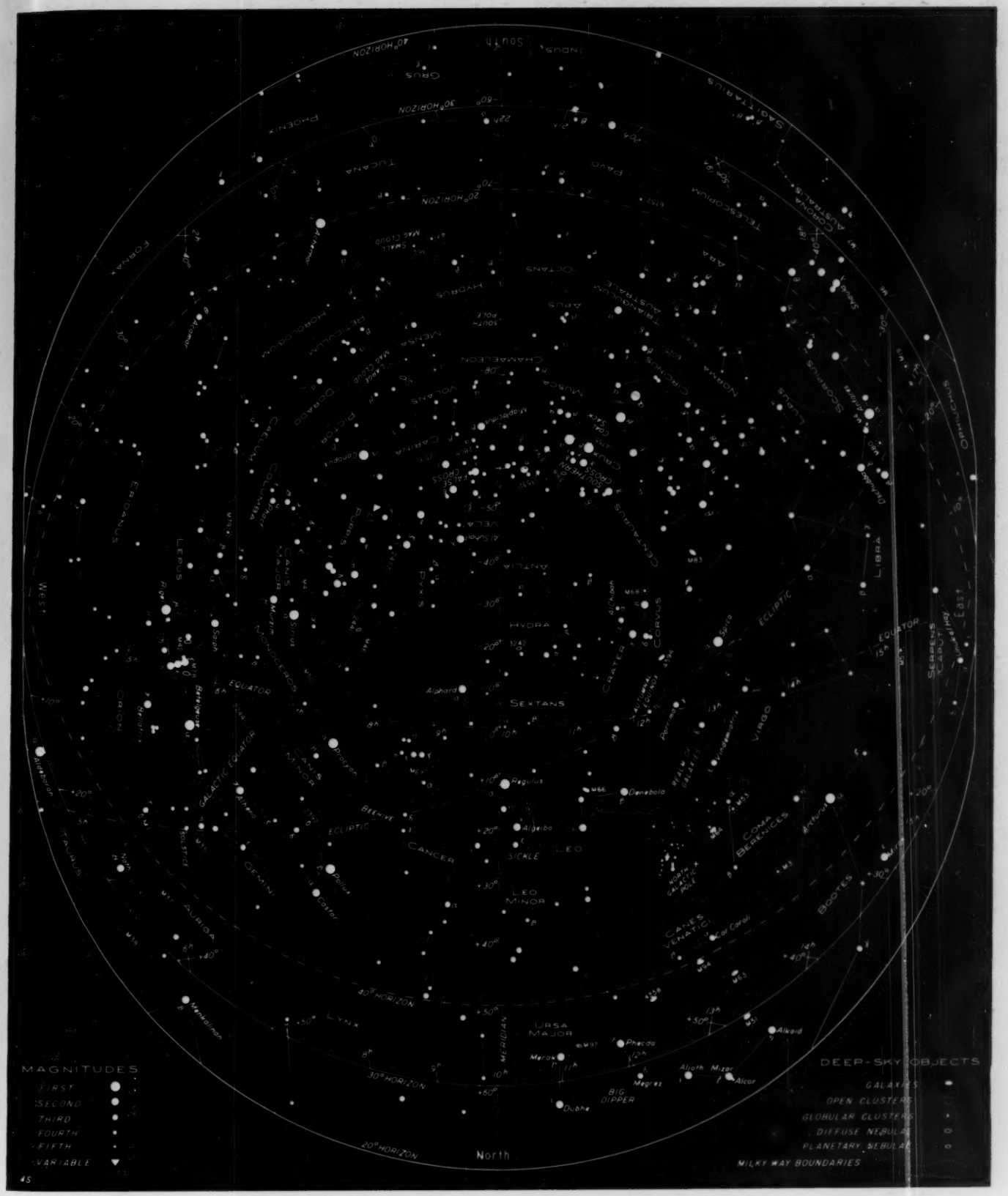
Columba. NGC 1851, $5^h\ 12^m.3$, —40° 06′; globular.

Canes Venatici. M51, $13^h\ 27^m.8$, +47° 27′; a twin galaxy, the Whirlpool. Situated near the end of the handle of the Big Dipper. Another nearby spiral is M63, $13^h\ 13^m.6$, +42° 18′; a bright oval, with a central nucleus.

L. S. COPELAND

STARS FOR JANUARY

from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.



EVENING STARS FOR SOUTHERN OBSERVERS

THIS CHART is prepared for a basic latitude of 30° south, but it may be used conveniently by observers 20 degrees on either side of that parallel. These southern charts appear in alternate months, but always two or three months in advance, to allow time for transmission to observers in any part of the world. The sky is here shown as it appears on March 7th at 11 p.m., March 23rd at 10 p.m., April 7th and 23rd at 9 p.m. and 8 p.m., respectively. Times for other days vary similarly, four minutes earlier per day. These are local mean times which must be corrected for standard time differences. The 30° horizon is a solid circle; the other horizons are circles, too, those for 20° and 40° south being dashed in part. When facing south, hold "South" at the bottom, and similarly for other directions. Observers in the tropics may find north circumpolar stars on any of our northern star charts. For other charts in this series, see issues of alternate months, August, 1944, to June, 1945, and July, 1945, to the present.